JOURNAL OF THE A·I·E·

FEBRUARY 1928

A E E I

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

WINTER CONVENTION, NEW YORK, FEBRUARY 13-17

Points of Interest Which Will be Visited During A. I. E. E. Winter Convention

1—System Operator's Office of New York Edison Company. 2—Lobby of Roxy Theatre. 3—Television Equipment at Bell Telephone Laboratories. 4—Hell Gate Station of United Light & Power Company. 5—Kearny Station of Public Service Electric & Gas Company. 6—Hudson Switching Station of Public Service Electric & Gas Company. 7—"Armor-Clad" Switchgear in Substation of New York Edison Company.

JOURNAL

OF THE

American Institute of Electrical Engineers

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33 West 39th Street, New York

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Vol. XLVII FEBRUARY, 1928 Number 2

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address be sure to mention the old one, indicating also any changes in business connections.

(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

MEETINGS
of
American Institute of Electrical Engineers

(See Announcements This Issue)

Winter Convention, New York, N. Y. (February 13-17, 1928)
St. Louis Regional Meeting, District No. 7 (March 7-9, 1928)
Baltimore Regional Meeting, District No. 2 (April 17-19, 1928)
New Haven Regional Meeting, Northeastern District No. 1 (May 9-11, 1928)
Summer Convention, Denver, Colo. (June 25-29, 1928)
Pacific Coast Convention, Spokane, Washington (Aug. 28-31, 1928)

Current Electrical Articles Published by Other Societies

Agricultural Engineering (December 1927)
Electrical Service for Rural Districts, by J. W. Purcell

American Society of Civil Engineers Proceedings (January 1928)
Virginian Railway Electrification, by G. Gibbs

Boston Society of Civil Engineers, Journal (December 1927)
West Buxton Hydroelectric Plant—Additional 5000-Kv-a. Unit, by G. E. Haggas

Central Railway Clubs of Buffalo, Proceedings (January 1928)
Dieselizing Railroads, by W. Arthur

National Electric Light Asso. Bulletin (December 1927)
Twenth-Five Years of Electric Power, by S. Insull

Iron & Steel Engineer (December 1927)
Electrical Safety Circuits—Their Uses and Construction, by W. M. Runyon
Year's Operation of Power Plant at Betty Furnace, Central Alloy Steel Corporation, by J. D. Donovan
Frequency Converter Speed Sets for the Carnegie Steel Company Upper Union Works, Youngstown, Ohio

Institute of Radio Engineers Proceedings (January 1928)
Method of Reducing the Effect of Atmospheric Disturbances, by Edwin H. Armstrong
Automatic Volume Control for Radio Receiving Sets, by Harold A. Wheeler
The Calibration of Ammeters at Radio Frequencies, by Herbert C. Hazel
Experiments and Observations Concerning the Ionized Regions of the Atmosphere, by Raymond A. Heising

JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

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Vol. XLVII — FEBRUARY, 1928 — Number 2

Electrical Communication at the Winter Convention

One of the outstanding features of the coming Winter Convention is the "Electrical Communication" session scheduled for Thursday morning, February 16. At this session greetings will be exchanged between the Institute and its sister society in London, England, by radiotelephone which will be heard by the members of both societies at meetings held simultaneously. Nothing could better illustrate the wonderful and spectacular advances in the art of electrical communication than a comparison of this meeting with one held by the Institute twelve years ago under the leadership of General John J. Carty, at that time president of the A. I. E. E.

On May 16, 1916, a National Meeting of the Institute was held simultaneously, by means of long distance telephone, in Boston, New York, Philadelphia, Atlanta, Chicago and San Francisco, with President Carty presiding over the entire meeting. The auditoriums in the six cities where the meeting was held were connected by telephone, and each of the 4500 members in attendance was provided with an individual telephone receiver. In addition, the Salt Lake and Denver Sections of the Institute were connected to listen in, but owing to the danger of interruption could not take active part in the meeting. The meeting was addressed by some of the leading engineers and educators of the country, and being the first meeting of its kind attracted nationwide attention. President Woodrow Wilson sent a telegram from the White House, Washington, congratulating the Institute on its work of developing the country's resources. At the close of the meeting, the following resolution presented by Prof. Harris J. Ryan at San Francisco, was passed:

RESOLVED, that this national meeting of the American Institute of Electrical Engineers at Boston, San Francisco, Atlanta, Chicago and New York now assembled, does hereby express its deep appreciation of the efforts of all those who have cooperated in the holding of such a meeting, which is now for the first time held in any country; and that a record of the proceedings of this meeting which is made possible by the inventive genius and by the engineering ability of its own membership, be spread upon the minutes of the Institute, where for generations to come it will serve as an inspiration to engineers everywhere, and will mark an epoch in the history of engineering achievement.

During the twelve years which have intervened, tremendous strides have been taken in the field of electrical communication. The developments in radio have abolished the need of physical connection by wire, and the introduction of loudspeakers has done away with the need for individual telephone receivers, so that the national meeting of 1916 is succeeded by an international meeting in 1928 under the leadership of President Gherardi. At this meeting greetings will be exchanged between two countries separated by 3000 miles of ocean; wired communication will be replaced by wireless and individual receivers are made unnecessary by the public address system. Today electrical communication is practically independent of distance, time, and wired connection, and of a quality which leaves but little room for improvement.

Notwithstanding the phenominal advances in this art the last word has by no means been spoken, and successful laboratory experiments have pointed the way to the commercial development of future improvements. Only a few days ago an experiment was reported in which the voice from a loudspeaker at the Bell Telephone Laboratories was distinctly heard on the opposite bank of the Hudson River, over a mile away. Television has reached a successful laboratory stage during the past year and its commercial development is certainly but a matter of time. Communication both by sight and hearing between all the nations of the world seems to be indicated as a not far distant accomplishment.

New Airway Lighting on Pacific Coast

In its program of lighting important air-mail and commercial airways, the Bureau of Aeronautics, Department of Commerce, has recently let additional contracts for the lighting of 390 miles of airway between San Francisco and Los Angeles, and surveys have been completed for extending the lighting to Redding, California.

The government also has under way plans which call for completion of airway lighting between Los Angeles and Seattle, Los Angeles and Salt Lake City and San Francisco and Salt Lake City within the coming year, a total distance of approximately 2500 miles. Revolving beacon lights are to be placed every 15 miles and illuminated emergency landing fields every 30 miles. Central station service will be utilized where available, otherwise a 2-kw. gas engine set will be

installed for beacon lights and a 4-kw. set for emergency landing fields.

Some Leaders of the A. I. E. E.

William Joseph Hammer, Vice-President of the Institute (1891-2 and 3), Manager (1893-4-5 and 6) and a Life Member and Fellow, was born at Cressona, Pennsylvania, Feb. 26, 1858. His early education was acquired at private and public schools in Newark, N. J., supplemented by attendance at university and technical school lectures abroad.

In 1878 he became an assistant to Edward Weston in the Weston Nickle Company and in Dec. 1879 entered Edison's laboratory at Menlo Park, N. J. as general assistant. For a time he had charge of the tests and records on the incandescent lamps and in 1880 was made the first chief electrician of the Edison Lamp Works which turned out 50,000 Edison lamps the first year. In October 1881 he was sent by Mr. Edison to the Paris Electrical Exposition, on his way to London to become chief engineer of the English Edison Co. Here he constructed the first central station for incandescent electric lighting in the world at Holborn Viaduct which started up Jan. 12, 1882. At the same time he installed the large plant using 12 Edison dynamos, at the Crystal Palace Electric Exposition and Edison's Paris Exhibit.

In 1883 he accepted the post of chief engineer of the German Edison Company, (now known as the Allegemeine Elektricitaets Gesellschaft), putting in many plants throughout Germany. Mr. Hammer invented the automatic motor-driven "flashing" electric lamp sign (now universal) placing it upon the Edison Pavilion at the Berlin Health Exposition in 1883. In 1884 he returned to the United States, taking charge of Mr. Edison's personal interests and 8 Edison Companies, exhibits at the Franklin Institute Elect. Exhibition later becoming confidential assistant to President Johnson of the parent Edison Company, and, with E. H. Johnson and Frank J. Sprague, an incorporator and trustee of The Sprague Company and its first secretary. In 1884-5 he was chief inspector of Central Stations of the Edison Company. In 1886-7 he was chief engineer and general manager of the Boston Edison Company. Acting as a contractor, he laid $140,000 worth of Edison underground tubing and with the Sprague agents installed 98 Sprague motors. Later acting as an independent engineer, he completed the lighting plant of the Ponce de Leon Hotel at St. Augustine, Fla., overhauled the Jacksonville Edison Plant which had been struck by lightning, and installed $40,000 worth of electrical effects at the Cincinnati Exposition of 1888.

Mr. Edison appointed him his personal representative at the Paris Exposition of 1889. Here he set up and operated all Edison inventions, a work for which in 1925, (34 years later), through the personal efforts of Mr. Edison, he was made Chevalier of the Legion of Honor by the French Government.

For his elaborate experiments in telephone relaying between New York and Philadelphia on Feb. 4, 1889, Mr. Hammer received the John Scott Medal from the Franklin Institute Feb. 5, 1902. Talking and music were sent through the air six times and through 15 separate mediums, the physical characteristics of the sound waves being changed 48 times in transmission and broadcasted by telephone from the Franklin Institute to 14 cities. Some of these experiments were repeated before the Electrical Jury at Paris in 1889. In 1896 he was president of the National Conference upon Standard Electrical Rules which originated "The National Electric Code," vice-president of the New York Electrical Society and The Aeronautical Society. Also expert and secretary of The Aeronautics Commission of the Hudson Fulton Celebration (1909), and in 1911 published a complete Aeronautical Chronology of Aviation.

In 1906 the Franklin Institute conferred upon him the "Elliott Cresson" gold medal for his "Historical Collection of Incandescent Electric Lamps" a work of 34 years. This "History of an Art" also received a silver medal at the Crystal Palace Expo. in 1882 and "The Grand Prize" from the St. Louis Expo. in 1904.

In 1902 Mr. Hammer brought from the Curie Laboratory in Paris 9 tubes of radium and took up actively work with radium. He delivered 88 lectures on radium before universities, colleges, scientific societies, etc. He wrote the first book published upon radium (1903) and proposed and used radium for cancer and tumor treatment. He also, in 1902, invented the "Radium Luminous Materials" which are now universally used for instrument dials, etc. He has done considerable original laboratory work upon selenium, radium, X-rays, cathode rays, ultra violet rays, phosphorescence, fluorescence, cold light, wireless, etc., and has contributed much to technical literature.

He is a Fellow of the American Physical Society, and the American Association for the Advancements of Science, was one of the founders of the Edison Medal Fund in 1908 and a member of its executive committee and President of the Edison Pioneers in 1920. During the World War, Mr. Hammer served as Major on the General Staff of the U. S. Army at the Army War College, Washington, D. C., being attached to the Inventions Section of the War Plans Division and later to the Operations Division at the War Department in charge of Electrical and Aeronautical War Inventions. He also did special work at the U. S. Patent Office, at times marking and holding up certain patents likely to convey information to the enemy and acting as a member of the Advisory Board of Experts attached to the Alien Property Commission. He was elected Historian General of The Military Order of the World War (1926-7-8) and a member of The Society of American Military Engineers.

Abridgment of

1926 Lightning Experience on 132-Kv. Transmission Lines

BY PHILIP SPORN[1]

Member, A. I. E. E.

General

FIG. 1 shows the 132-kv. transmission network in question. It comprises approximately 910 mi. of actual line, about one-third of which is double-circuit, the actual circuit miles being approximately 1245. The major portion of this network was placed in operation very late in 1925, in 1926, or early in 1927.

The system is fed by large generating stations at Twin Branch, Philo, Windsor, Kenova, Cabin Creek, Logan and Glen Lyn. It is tied in with the Chicago system and the systems of the West Penn Power Company, The Ohio River Edison Company, The Ohio

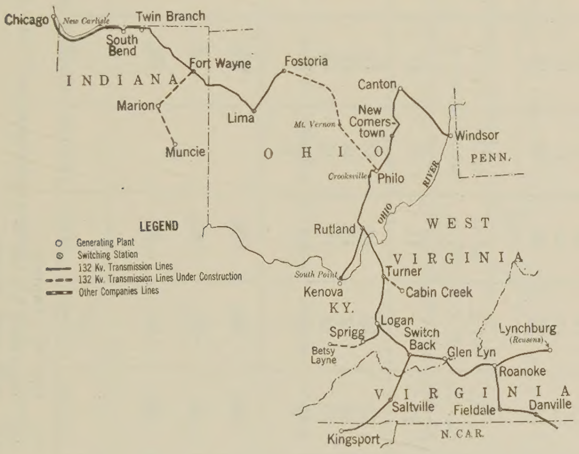

FIG. 1

Public Service Company, and the Cleveland Electric Illuminating Company at 132,000 volts. The short-circuit capacity on the system varies from approximately 1750 amperes to approximately 4750 amperes, at 132,000 volts. Values as high as 4000 amperes have been actually measured.[3] From a lightning standpoint, the network as a whole is subjected to thunderstorms considerably in excess of the average over the country as a whole. The isoceraunic lines, *i. e.*, lines connecting points of equal thunderstorm intensity, for the territory in question ranged from 40 to 60 in April, 150 to 200 in June and July, and down to about 60 to 80 in September. All these figures are based on a 20-year period.

Description of Lines and 1926 Performance

In Table I there is given a description of the physical characteristics of the various portions of the 132-kv. network under discussion.

Examining Table II, it will be noted, first, that the largest number of lightning outages occurred on the Twin Branch-Lima line. This line checks up with similar performance on the Lima-Fostoria line, and on the Philo-Crooksville line. On the basis of 100 line mi. the largest number of interruptions occurred on the Glen-Lyn-Roanoke line, but this figure is of course subject to the weakness that the line was in service for 6 months only, and there is no way of checking up whether the ratio employed for figuring the yearly number of interruptions was correct for the entire year.

Of the lines that were in service for an entire year the largest number of interruptions per 100 mi. of line was sustained by the Logan-Turner line. This is a line that has no ground wires and, in addition, passes through especially rugged country. The length of the insulator string on this line is particularly short (as shown in Table I) being, in fact, shorter than that of any other line with the exception of the Windsor-Canton line. Expressed in circuit miles, however, the record is rather good.

The Roanoke-Reusens line is third in the number of interruptions per 100 mi. of line, but the figure for a whole year was again obtained by a ratio, and is open to the same objections as the figures for the Glen-Lyn-Roanoke lines. The Philo-Canton and the Windsor-Canton lines, in spite of the fact that the Philo-Canton line generally is exposed to more severe storms than the Windsor-Canton line, have practically the same record for the year 1926, when reduced to a 100-mi. basis. The Windsor-Canton line, has two ground wires and is considerably lower than the Philo-Canton line which has only one ground wire. The record during 1926 would seem to show that, from the standpoint of reliability, the Philo-Canton line, even though it has only one ground wire, has been put on a plane of apparently equal to that of the Windsor-Canton line. From the data gathered on the Glen-Lyn-Reusens line and Roanoke-Reusens line in 1926, it would seem that the ground wire on these lines was not so effective as it was on the other lines. The ground wire construction being in general the same on all of the lines, a possible explanation for the large number of flashovers may lie in the fact that the tower resistance over the lines as a whole is rather high. Some of the

1. Electrical Engr., Am. Gas & Electric Co., New York, N. Y.

3. *Tests of High- and Low-Voltage Oil Circuit Breakers*, Sporn and St. Clair, JOURNAL A. I. E. E., July 1927, p. 698.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Feb. 13-18, 1928. Complete copies on request.

TABLE I

CHARACTERISTICS OF 132-KV. LINES—AMERICAN GAS AND ELECTRIC COMPANY

Column No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Line designation	Glen Lyn Roanoke	Glen Lyn Switch-back	Lima Fostoria	Lima Tw. Branch	Logan Sprigg	Philo Canton	Philo Crooks-ville	Philo Turner	Roanoke Danville	Roanoke Reusens	Rutland So. Point	Salt-ville Kings-port	Switch-back Logan	Switch-back Salt-ville	Turner Logan	Tw. Branch So. Bend	Windsor Canton	So. Bend New Carlisle
Initially placed in service	6/13/26	8/13/27	9/3/25(e)	9/18/25	6/28/26	9/28/24	9/28/24	4/22/26	9/16/26	5/5/26	3/15/26	8/25/27	11/27/27	10/16/27	1/30/26	4/5/25	9/–/17	6/24/26
Length of line—(Miles)	65.0	30.0	45.6	128.5	21.0	73.	15.4	118.7	65.0	43.0	50.3	56.0	50.0	46.0	40.2	4.9	55.0	17.7
Number of circuits	2	2	1	1	1	2	1	1	1	1	1	1	2	1	2	2	2	1
Size of conductor wire—(C. M.) A. C. S. R.	397,500	397,500	336,400	397,500	4/0	336,400	336,400	397,500	336,400	397,500	397,500	397,500	397,500	397,500	336,400	397,500	200,000(a)	397,500
Number of ground wires	1	1	1	1	None	1	1	1	1	1	1	1	1	1	None	1	2	1
Size of ground wire—(C. M.) A. C. S. R.	397,500	397,500	159,000	159,000	None	159,000	159,000	159,000	159,000	197,500	159,000	159,000	397,500	159,000	None	159,000	159,000	159 000
Date ground wire installed	6/13/26	8/13/27	5/15/26	6/7/26	None	5/6/26	4/9/26	4/22/26	9/16/26	5/5/26	3/15/26	8/25/27	..	10/16/27	None	6/8/26	9/–/17	6/24/26
Line configuration—(Horizontal-Vertical)	V	V	V	V	H	V	V	V	V	V	V	V	V	V	V	V	V	V
Protection—Rings and horns	No	Yes	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No
Protection—Horns line side	Some	..	Some	..	..	..	..	Yes	Some	..	..	..	..	..	..	..	Some	Some
Protection—Horns ground side	Some	Yes	Some	Yes	..	Yes	..	..	Some	Yes	..	Yes	Yes	Yes	Yes	Yes	Few	Some
Nature of terrain	Rolling to moun-tainous	Very moun-tainous	Very flat	Very flat	Very moun-tainous	Rolling	Rolling	Rolling to moun-tainous	Rolling	Rolling	Rolling	Rolling to moun-tainous	Very moun-tainous	Moun-tainous	Very moun-tainous	Very flat	Rolling	Flat
Length per insulator—(Inches)	4–3/4	5–1/8	4–3/4	5–3/4	6–7/16	4–3/4	4–3/4	4–3/4	5–1/8	5&4–3/4	4–3/4	5–1/8	5–1/8	5–1/8	5&4–3/4	5–3/4	4–3/4	5–3/4
Insulators per string (Suspension) Top	11	11	12	10	10(b)	11	12	12	11	12	12	10	10	10	10	10	10	10
Middle	11	11	12	10	10×10M	11	12	12	11	12	12	10	10	10	10	10	10	10
Bottom	10	10	10	9	10(b)	10	10	10	10	10	10	10	10	10	10	9	10	9
Length of susp. ins. string (Inches) Top	52.25	56.38	57.0	57.5	64.4	52.25	57.0	57.0	56.38	57.0	57.0	51.3	51.3	51.3	47.5	57.5	47.5	57.5
Middle	52.25	56.38	57.0	57.5	64.4	52.25	57.0	57.0	56.38	57.0	57.0	51.3	51.3	51.3	47.5	57.5	47.5	57.5
Bottom	47.50	51.3	47.5	51.75	64.4	47.50	47.5	47.5	51.3	47.5	47.5	51.3	51.3	51.3	47.5	51.75	47.5	51.75
Dead ends—(Single or double)	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Insulators per string (Dead end) Top	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	11
Middle	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	11
Bottom	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	11
Type towers	A-B-C-E	G-H-K-E	A-B-C	A-B-C	Wd. pole (c)	A-B-C	A-B-C	A-B-C-E	A-B-M-P	A-B-C	A-B-C	AA-BB-CC-E	G-H-K-E	AA-BB-CC-E	B-C-E	A-B-C	Ao-Bo	A-B-C-G
Total number of towers	269		215	603	189	298	69	425		199	191				155	24	487	82
Number of towers with 10′ extension	35		78	188	..	71	13	67		19	26				2	5	101	23
Number of towers with 20′ extension	55		48	166	..	48	12	51		39	38				4	7	23	19
Number of towers with 30′ extension	..		..	2	..	1	..	..		0	2				0	..	..	2
Number of towers with 40′ extension	..		..	..	..	..	..	..		0	..				4	..	2–50′	..

(a) Copper conductor
(b) Sides—some with 9 insulators
(c) With steel crossarms
(d) On "E" Towers
(e) Operated 8/3/24 to 9/3/25 @ 66 kv.
(f) Side cond. to pole
(g) Center to outside conductor
(h) To wood pole. 4.0′ deg. to crossarm
(x) "E" Towers

TABLE I—*Continued*

CHARACTERISTICS OF 132-KV. LINES—AMERICAN GAS AND ELECTRIC COMPANY

Column No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Line designation	Glen Lyn Roanoke	Glen Lyn Switch-back	Lima Fostoria	Lima Tw. Branch	Logan Sprigg	Philo Canton	Philo Crooks-ville	Philo Turner	Roanoke Danville	Roanoke Reusens	Rutland So. Point	Salt-ville Kings-port	Switch-back Logan	Switch-back Salt-ville	Turner Logan	Tw. Branch So. Bend	Windsor Canton	So. Bend New Carlisle
Average length of span—(Feet)	1270		1102	1125	585	1295	1160	1470		1140	1376				1360	1016	595	1125
Maxmium length of span—(Feet)	3321		1400	1775	2220	2665	2200	3050		2135	2858				3770	1375	1550	1876
Minimum length of span—(Feet)	100		745	610	85	360	480	410		434	465				280	520	150	156
Height of std tower (Gr. to top crossarm (Ft.)	90	92	90	90	35–40	90	90	90	92	90	90	90½	92	90½	90–45(x)	90	74	90
Conductor spacing (vertical) (Ft.) Top—Mid	13	15	13	13	..	13	13	13	15	13	13	13½	15	13½	13	13	12	13
Mid.—Bot	13	15	13	13	..	13	13	13	13	13	13	13	13	13	13	13	12	13
Conductor spacing—(Horizontal) (Ft.) Top (For standard towers)	21.75–23 21.75(d)	26.75–28 21.75(d)	26.75–23	26.75–23	15.0(g)	26.75–23	26.75–23	26.75–23 21.75(d)	26.75–28	21.75–23	21.75–23	24.75–26 21.75(d)	26.75–28	24.75–26	23 21.75(d)	26.75–23	21.75	26.75–23
Middle	26.75–28 21.75(d)	31.75–33 21.75(d)	26.75–28	26.75–28	..	26.75–28	26.75–28	26.75–28 21.75(d)	31.75–33	26.75–28	26.75–28	29.75–31 21.75(d)	31.75–33	29.75–31	28 21.75(d)	26.75–28	31.75	26.75–28
Bottom	21.75–23	26.75–28	21.75–23	21.75–23	..	21.75–23	21.75–23	21.75–23	26.75–28	21.75–23	21.75–23	24.75–26	26.75–28	24.75–26	23	21.75–23	21.75	21.75–23
Clearance—Line to tower (Normal pos.) Top	6.0	6.5	5.75	5.75	7.0(f)	6.0	5.75	5.75	5.0	5.75	5.75	5.0	7.0	5.0	5.0	5.75	5.25	5.75
At suspension strings–(Ft). Middle	6.5	6.5	6.25	6.25	5.0	6.5	6.25	6.25	6.5	6.25	6.25	6.75	7.0	6.75	7.25	6.25	9.0	6.25
Bottom	7.5	10.0	7.5	7.5	7.0(f)	7.5	7.5	7.5	9.75	7.5	7.5	9.0	10.0	9.0	7.5	7.5	7.75	7.5
Clearance—Line to tower—(45 deg. Pos.) Top	4.8	5.0	5.0	5.0	3.25(h)	4.8	5.0	5.0	4.8	5.0	5.0	4.0	4.0	4.0	3.75	5.0	3.25	5.0
At suspension strings–(Feet) Middle	4.8	5.0	5.0	5.0	..	4.8	5.0	5.0	4.8	5.0	5.0	4.0	4.0	4.0	3.75	5.0	3.25	5.0
Bottom	3.75	4.0	3.75	3.75	3.25(h)	3.75	3.75	3.75	4.0	3.75	3.75	4.0	4.0	4.0	3.75	3.75	3.25	3.75

(a) Copper conductor
(b) Sides—some with 9 insulators
(c) With steel crossarms
(d) On "E" Towers
(e) Operated 8/3/24 to 9/3/25 @ 66 kv.
(f) Side cond. to pole
(g) Center to outside conductor
(h) To wood pole. 4.0 deg. to crossarm
(x) "E" Towers

TABLE II

OPERATING RECORD OF 132-KV. LINES—AMERICAN GAS AND ELECTRIC COMPANY

Column No. 1	2	3	4	5	6	7		8	9	10	11	12	13	14	15	16	17	18	19
Line designation	Glen Lyn Roa-noke	Glen Lyn Switch-back	Lima Fos-toria	Lima Tw. Branch	Logan Sprigg	Philo Canton		Philo Crooks-ville	Philo Turner	Roa-noke Dan-ville	Roa-noke Reusens	Rut-land So. Point	Salt-ville Kings-port	Switch-back Logan	Switch-back Salt-ville	Turner Logan	Tw. Branch So. Bend	Wind-sor Canton	So. Bend New Car-lisle
						1925	1926												
Outages (One circuit only) Due to lightning—1926	16	..	9	23	3		13	3	11	0	13	3	..	..	..	16	0	9	0†
Circuit outages due to lightning—1926	20	..	9	23	3	88	15	3	11	0	13	3	..	..	..	18	0	11	0†
Circuit outages per 100 mi. of line per yr.—1926	48*	..	19.8	17.9	31*	120	20.5	19.5	10.6*	0	36.6*	6.3*	..	..	..	44.8	0	20	0†
Circuit outages per 100 mi. of circuit per yr.—1926	24*	..	19.8	17.9	31*	60	10.3	19.5	10.6*	0	36.6*	6.3*	..	..	..	22.4	0	10	0†

*Corrected for one calendar year on basis of Fig. 3.
†Record incomplete.

operating data cited by Hemstreet[5] showed that there is a definite relationship between the number of flashovers and the ground resistance in the particular section.

An interesting line in the series is the Logan-Sprigg line. This line, of wood pole construction, was originally built for 88,000 volts and was operated for a period of about five years at 44,000 volts. At the end of this time, additional insulation was added and the line was cut over to 132,000-volt operation. The majority of the structures are 2-pole A frames with ungrounded steel crossarms. The insulation is unusually liberal. For a while, when the line was first

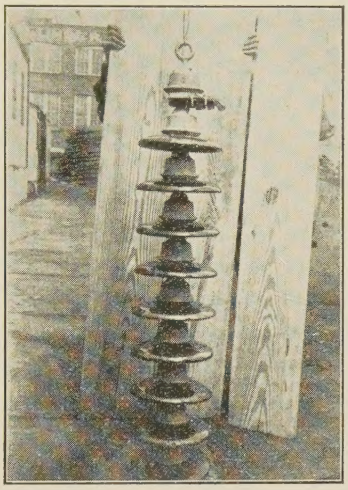

Fig. 5—Result of Typical Flashover of 132-Kv. Insulator String Without Arcing Protection

(Note badly shattered insulator on ground side)

placed in operation, the operating records seemed to indicate an almost lightning-proof line, but detailed investigation has shown that this was not quite so. Considering the shortness of the line,—namely 21 miles,—the record is not particularly good although, again, the record is open to the criticism because a full year's data were not available.

The rest of the data require no particular comment.

Design Developments During 1927

1. Whereas in 1926 an extensive program of ground wire installation was carried out, in 1927 much more attention than in the past was given to a phase that had been apparently neglected, and that was the problem of the line entrance. In every case, the ground wire was brought into the station structure and where the station structure design allowed, the number of ground wires brought into the station structure was made larger than the number on the line itself, all with the idea of reducing as much as possible the surge impedance of that portion of the system running from the last tower to the bus.

2. In connection with the work discussed above and along the lines of limiting definitely the amount of overvoltage that can be brought into the station apparatus a reduction in the insulating value on the first mile or so of the line coming into the station was made, all with the idea of making certain that the lightning strength of the apparatus connected to the bus was equal to, or greater than, the lightning flashover of the insulator string on the first mile of line.

3. In the design of the new lines, where the country did not absolutely demand it, the use of tower extensions has been kept at a minimum so as to keep the effective height of the line at a predetermined level, that level being determined, of course, by the tower design itself. In cases where the topography of the country permitted, the tension to which the conductor was pulled up was considerably reduced, resulting in a greater sag and a closer adherence of the conductor to the contour of the earth, with, of course, a net reduction of the average height of span above earth.

4. More attention was paid to the mechanical

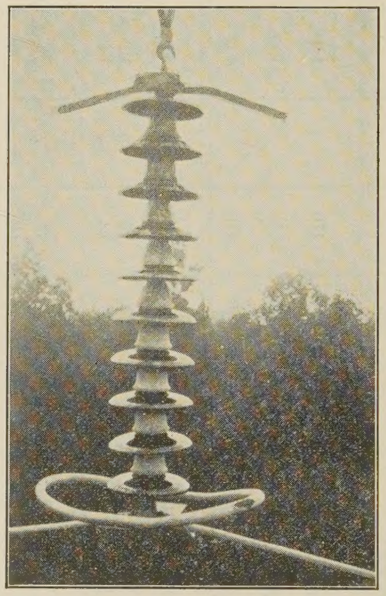

Fig. 7—Result of Typical Flashover of 132-Kv. Insulator String With Stanard Ring and Horn Protection

(Note burned ring above conductor; also horn tip slightly burned. Insulator undamaged)

aspect of the arcing protection arrangements with a view of minimizing the effects of conductor vibration on the protection assembly itself.

Summation of Experience and Its Application to Tower Line Design

There is only one point that should be stressed, and that is, with regard to the question of ground wire. Previously it was pointed out that unless a line was very low, generally steel tower structures, carrying power conductors of 44,000 volts and over, should be designed and installed with a ground wire. It is now believed that careful consideration should be given to

5. *Recent Investigation of Transmission Line Operation.* J. G. Hemstreet, Journal A. I. E. E., November 1927, p.1221.

the question of whether or not two ground wires would not, in some cases be justifiable with of course particular attention to the location of the ground wires as regarded the main conductors. The experience with lines without ground wires, and particularly the experience obtained during 1926, on the Logan-Sprigg and Turner-Logan lines, would seem to prove definitely that it is very hazardous and extremely unwise to try to operate a line of the type under discussion, without a ground wire.

Abridgment of

The Stability of the Welding Arc

BY P. ALEXANDER*
Member, A. I. E. E.

Introduction

THE term "stability" of the welding arc can be interpreted in various ways and in accordance with conditions under which the welding arc is used.

In this paper, only one phase of the problem is discussed; namely, the influence of the various gases on the arc conduction of the current and the voltage necessary to maintain that arc. The stability of the arc is judged here by the average voltage drop across the short iron welding arc.

Arc Conduction

The metallic welding arc is a combination of two factors, distinct, yet dependent upon one another. The conduction of the electric current is one factor and the transfer of the material across the arc stream is another factor. Both these factors are greatly influenced by the gas surrounding the arc. The first factor perhaps is more directly affected; therefore, only the first one will be discussed in this paper.

It is a well established fact that the conduction of the electric current in the arc is an ionic phenomenon. At any instant in a given volume of the arc core, there is about an equal number of electrons and positive ions. These carriers of the electric charges travel under the influence of the electrostatic field in opposite directions, the electrons migrate toward the anode and the positive massive ions bombard the surface of the cathode spot.

It is this bombardment by the positive ions that keeps the temperature of the cathode sufficiently high to permit the thermionic emission of the electrons.

Since the electrons are moving at a much higher velocity than the positive ions, the relative number of these carriers is not the same. The number of electrons greatly exceeds the number of positive ions passed through the arc in a unit of time so that practically the total current is carried by the electrons.[1] Yet without the continual production of the positive ions, the arc phenomena would be impossible; hence, both factors play equally important roles and any condition affecting one of these factors (or both of these factors at the same time) will have a great influence on the stability of the arc.

Thermionic Emission of Electrons from the Cathode

The first factor,—that is, the thermionic emission of the electrons from the cathode,—is a function of temperature and is expressed by the well-known Richardson's formula $I = A\,\theta^{1/2}\epsilon^{-\frac{Q}{2\theta}}$, where A, Q and ϵ are constants and θ the absolute temperature of the substance. Temperature is the first and the most important factor. The second factor lies in the nature of the material of the cathode. Various substances at the same temperature will emit very different electronic currents. Among the substances giving the largest thermionic emissions, calcium oxide holds a marked place.

If calcium oxide be present in sufficient amount on the surface of the electrode of a vacuum tube, the thermionic emission may increase several hundred times over that produced by an electrode, made, for example, of pure iron. In case of the arc conduction of the current, it may be expected that Ca O present on the surface of the electrode will also greatly facilitate the maintenance of a stable arc. The third factor affecting the thermionic emission from the cathode is the gas surrounding the cathode. Various gases influence this emission in different degrees. The gas that has the most marked effect is hydrogen. Owing to its strong electropositive nature, the first gaseous layer next to the cathode creates such a steep potential gradient that the electrons will escape the surface of the cathode with great facility.

Taking again the example of calcium oxide, it is established that the thermionic emission from that compound surrounded with hydrogen increases very considerably. The thermionic current from incandescent calcium oxide in air at low pressure is 0.05 amperes per square centimeters. If hydrogen replaces the atmospheric gases, the thermionic current at the same temperature will be 1000 amperes per sq. cm. of the cathode spot. Even a trace of hydrogen is sufficient to increase the thermionic emission.[2]

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1. See references end of article.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., February 13-18, 1928. Complete copies upon request.

Ionization

Passing, now, to the consideration of the ionization, the first factor to be analyzed is the ionizing potentials of the materials present in the state of gas or vapor in the space between the electrodes.

The ionizing potential expressed in the equivalent volts is the potential through which the electron must fall to acquire sufficient energy to ionize the gaseous atom or molecule. The amount of energy necessary to produce this effect is proportional to the stability of the atomic structure. Since the helium atom possesses the most stable atomic structure, the ionizing potential for that gas is the highest. After helium comes neon, and soon, until calcium, and finally caesium, which requires the least energy for ionization, is reached.

TABLE I
IONIZING POTENTIALS[3]

Name	Atomic Number	Symbol	Ionizing Potentials Volts
Helium	2	He	24.5
Neon	10	Ne	21.5
Argon	18	A	15.3
Oxygen	8	O	13.56 – (15.5)*
Hydrogen	1	H	13.53 (15.9)
Phosphorus	15	P	(13.3)
Nitrogen	7	N	10.8 – (16.9)
Mercury	80	Hg	10.39
Sulphur	16	S	(10.31)
Zinc	30	Zn.	9.35
Silicon	14	Si	8.50
Copper	29	Cu.	7.69
Silver	47	Ag	7.54
Iron	26	Fe	7.4
Manganese	25	Mn	7.4
Lead	82	PG	7.39
Molybdenum	42	Mo	7.1
Chromium	24	Cr	6.7
Titanium	22	Ti	6.5
Calcium	20	Ca	6.09
Aluminum	13	Al	5.96
Barium	56	Ba	5.19
Sodium	11	Na	5.13
Potassium	19	K	4.1
Caesium	55	Cs	3.9
Acetylene	C_2H_2		(12.3)
Carbon Monoxide	CO		(14 3)
Carbon Dioxide	CO_2		(14.3)

*Values in parentheses refer to molecules.

From the examination of the Table I, it may be concluded that if the vapors of alkaline earths, or alkal imetals, be present in the space between the electrodes striking and maintaining the arc would be much easier than in air. The voltage required to strike the arc and the voltage across the established arc will be lower. This conclusion is quite in accord with the experimental data.[4]

From the table above it may also be seen that the ionizing potentials of monatomic gases are very much higher than those of molecular gases. Helium, for instance, has the highest ionizing potential,—namely, 24.5 volts,—whereas the ionizing potential of nitrogen is 16.9 volts.

And yet it requires much lower open-circuit voltage to strike the arc in helium than in nitrogen. With certain precautions, 20 volts is sufficient to strike the arc in helium, whereas at least 30 volts is necessary to strike the arc in nitrogen.[5]

This apparent paradox can be explained by the fact that in monatomic gases the electron impacts below the ionizing or radiating potentials are elastic. In helium, for instance, the electron impacts below 20 volts (minimum radiating potential) are elastic. The electron does not lose its energy at the first or second collision, but rebounds and proceeds in a zigzag course until it falls through the potential giving it sufficient energy to bring the helium atom into an excited state at the next impact. If an excited atom already having absorbed 20 volts, is again hit with an electron of sufficient energy, then the helium atom will be ionized.

This preservation of the energy of the bombarding electron during the successive impacts explains the possibility of drawing the arc in helium with lower open-circuit voltage than in nitrogen.

In nitrogen as in all diatomic gases the electron impacts are not elastic. In that case the accumulation of energy by an electron falling through the potential should be sufficiently fast so that in spite of continual losses during the encounter with the molecules, it will be able to acquire energy sufficient to ionize. Therefore the striking voltage in molecular gases must be considerably higher than in monatomic gases.

Cooling of the Arc

The next factor affecting the ionization is the dissipation of energy and therefore the cooling of the crater and the arc core. It is a well established fact that it requires much greater voltage to strike the arc with water-cooled electrodes than with electrodes allowed to become incandescent.[6]

The gases surrounding the electrodes and the arc core in certain cases cause such effective cooling that the arc voltage, or the voltage necessary to strike the arc, are very much higher. If the open-circuit voltage of the welding generator is not increased, the arc becomes very unstable.

From an examination of the tables giving the physical constants of the gases, it may be seen that helium has the highest coefficient of heat conductivity; namely, 0.000339 calories per deg. cent. Yet the cooling effect of that gas on the arc is not much different than that of air of which the coefficient of heat conductivity is only one-sixth as great; namely, 0.0000568 calories. On the other hand, if helium be compared with hydrogen, which has about the same coefficient of heat conductivity (0.000327), it will be found that the cooling effect of hydrogen is many times greater than that of helium. This indicates that the cooling effect of the gas is a function of some other much more powerful factor than the mere dissipation of heat by conduction.[7]

The well-known experiments conducted by Dr.

Langmuir, on heat losses from incandescent tungsten filaments placed in hydrogen, established that the powerful cooling effect of that gas is due to the absorption of energy by dissociation at high temperature of the molecular hydrogen into the atomic state.[8] However, the mere fact of the dissociation of the molecules into the atomic state is not sufficient to produce the cooling effect. To produce this, the dissociation products should diffuse away from the arc core so that the recombination of the atoms into molecules with the inevitable restoration of the absorbed energy will occur at sufficient distance from the arc core. Otherwise, there will be an immediate restitution of the absorbed energy, which excludes the possibility of the cooling effect. The most energetic cooling effect produced by hydrogen is due not only to the fact that the whole mass of that gas in the first gaseous layers next to the arc core is dissociated into atomic state, but also to the fact that the atomic hydrogen rapidly diffuses away from the arc core.

The gas most commonly met in welding is, of course, *nitrogen,* since it constitutes 78 per cent of the ordinary air. This gas also dissociates into the atomic state in the first gaseous layers next to the arc core. The heat of dissociation of nitrogen is 274,000 calories per molecule,—that is, almost three times as great as that of hydrogen (98,000 calories per molecule)—so that it has the greatest capacity for absorbing energy from the arc. If the products of dissociation, namely, the atomic nitrogen, could be blown away from the arc in the same way as the atomic hydrogen is blown away from the arc, the atomic nitrogen would be three times as efficient as a heat transmission medium as the atomic hydrogen. However, the dissociation of nitrogen into the atomic state does not begin until the temperature is 3500 deg. cent., whereas the dissociation of hydrogen is appreciable already at 1800 deg. cent. Certain percentage of nitrogen is dissociated in the first gaseous layer next to the arc core, but as soon as it leaves that region, it recombines into the molecular state, with a complete restoration of the absorbed energy. Therefore the cooling effect of this reaction is neglible.

The carbon monoxide presents an interesting subject for study because in spite of a very high heat of dissociation and a comparatively high ionizing potential, it is the gas in which the welding arc can be maintained with the greatest ease.

The heat of dissociation of carbon monoxide as calculated from the band spectra is 258,000 calories per molecule.[9] If, in spite of this enormous heat of dissociation, this gas does not produce any appreciable cooling of the arc, either it is not dissociated by the arc or the products of dissociation cannot be blown off the arc, but recombine in the immediate vicinity of the arc core with full restoration of the absorbed energy.

For the purpose of elucidating this interesting point if possible the writer made the following series of experiments:

After preparing and purifying a sufficient amount of carbon monoxide, a stream of that gas was passed through a cylindrical fused clear quartz vessel in the middle of which were disposed two tungsten electrodes. The flow of the gas was adjusted so as to duplicate as nearly as possible the conditions of an actual welding operation if such were made with carbon monoxide as a shielding gas. By bringing into contact and then withdrawing the tungsten electrodes, an arc of 30 amperes and 28 volts was established in the stream of gas for one minute. At the end of 60 sec., the arc was hardly visible through the black deposit on the inside walls of the vessel.

The following conclusions may be drawn from the above observations: Since the three known oxides of carbon, namely, $C\,O$, $C\,O_2$, and $C_2\,O_3$, are not solids at room temperature, the black deposit could be either pure carbon, a mixture of carbon and condensed tungsten vapor, or tungsten carbide. The chemical analysis of the deposit indicated, however, that the black deposit was carbon.

The experiments repeated with various mixtures of H_2 and $C\,O$ indicated that the presence of H_2 does not prevent the formation of the black deposit. The dilution of $C\,O$ with hydrogen merely reduces the amount of the deposit per unit time. However, when the experiment was repeated in pure argon, the walls of the vessel remained perfectly clear.

It may be concluded that carbon monoxide is dissociated by the arc and that one of the products of dissociation was diffused away.

This is an apparent contradiction to the well-known fact that the dissociation of carbon monoxide begins only at extremely high temperature. Therefore in this respect the gas should behave like nitrogen. This contradiction, however, is apparent only, since that reaction took place in the presence of readily oxidizable materials, and the heat of formation of the secondary reactions of the liberated oxygen, and probably a part of carbon, compensates for the cooling effect of the first reaction.

Also, since the gas has a smoky appearance in the immediate vicinity of the arc core, it may be inferred that the liberated carbon was condensed into the solid state in the region next to the arc core. Since the heat of sublimation of carbon is quite accurately known it is possible to represent the above reaction by the equation:[10]

$$C \text{ (gaseous)} = C \text{ (solid)} + 141{,}000 \text{ calories}$$

so that even in the absence of other secondary reactions of oxidation and carboration of the electrodes, the condensation of carbon alone restores the greatest part of the energy previously absorbed from the arc core.

The oxidation of tungsten,—that is, formation of

WO_2 or WO_3,—gives respectively 131,400 and 196,300 calories per molecule.

In the case of iron the formation of Fe_3O_4 produces 197,700 and 270,800 calories respectively. In other words, the condensation of the gaseous carbon and the oxidation reaction supply an ample amount of heat to neutralize completely the cooling effect of the first reaction.

The most remarkable property of carbon monoxide is its stabilizing influence of the welding arc burning in any gas to which carbon monoxide is added in sufficient amount.

The property is quite astonishing because the ionizing potential of this gas is quite high; namely, 14.3 volts. However, it can be observed that only a certain percentage will be dissociated the rest of gas will be in molecular form and that with regard to the ionization by successive electron impacts carbon monoxide behaves in an astonishingly similar manner to mercury vapor.[11] Owing to the existence of several critical potentials, both these gases may accumulate the energy necessary for ionization by steps, and is in mercury vapor, so in carbon monoxide gas it is possible to maintain an arc with a very low voltage.

Carbon dioxide gas is dissociated in the arc into oxygen and carbon monoxide. A part of the produced carbon monoxide will undergo further dissociation into carbon and oxygen. However, in the presence of an excess of carbon dioxide, the amount of dissociated carbon monoxide will be very small.

The heat of dissociation of carbon dioxide into oxygen and carbon monoxide is 68,000 calories per molecule. If the products of dissociation are blown off the arc, it will be always burning in carbon dioxide which through its dissociation will produce a very strong cooling effect causing instability of the arc.

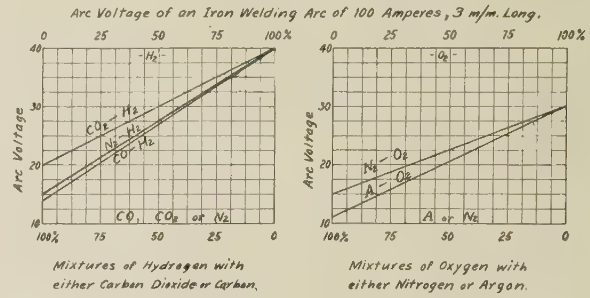
The voltage drop may be as high as 30-35 volts and the arc will be very unstable. If, however, the arc is maintained in a more or less stationary atmosphere of the dissociated carbon dioxide, it will be stable, and the arc voltage of an arc of say 175 amperes will be only 19 volts.

CO_2	Carbon dioxide	N_2	Nitrogen
CO	Carbon Monoxide	A	Argon
H_2	Hydrogen	O_2	Oxygen

The following curves show the relationship between the composition of gaseous mixtures of hydrogen, carbon monoxide, carbon dioxide, argon, nitrogen and oxygen and the arc voltage.

CONCLUSIONS

The stability of the iron welding arc is influenced by a number of factors, such as the nature and the aerodynamic state of the surrounding atmosphere, the strength and distribution of the magnetic field, the composition of the electrode, the nature and the amount of gases occluded in the electrode, etc. In this paper however, only the first item has been discussed in an attempt to show that the cooling of the



electrode and the arc core has the preponderent influence on the stability of the arc.

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LIVING 62 PER CENT UP; LIGHT 13 PER CENT DOWN

The cost of living in the United States in July, 1927, was 62 per cent above the cost of living in 1914, according to figures just released by the National Electric Light Association; while electricity in the home was 13 per cent below its 1914 cost. The N. E. L. A. has for its authority the National Industrial Conference Board. This Board bases its report on data from 143 cities in the United States, aggregating 32,695,000 population.

Intense effort is being devoted at this time to promotion of first class office, industrial and home lighting. It is meeting resistance—resistance which was expected, but which is discouraging to some. The following table should be a spur to them.

	Relative Importance in Pre-war Budget Per cent	Relative Cost July 1914	July 1927
Food	43.1	$1.00	$1.53
Shelter	17.7	1.00	1.68
Clothing	13.2	1.00	1.69
Coal	3.7	1.00	1.80
Gas	1.27	1.00	1.34
Electricity	0.63	1.00	.87
Sundries	20.4	1.00	1.73
Weighted average, all items	100.00	$1.00	$1.62

—*Light*, November, 1927.

Abridgment of

Vacuum Tube Synchronizing Equipment

By T. A. E. BELT[1] Member, A. I. E. E.

and

N. HOARD[1] Non-member

Synopsis.—Potential from high-voltage circuits is obtained by means of capacitance transformers. This potential is applied to the grid circuit of vacuum tube amplifiers the output from which drives a rotating type of synchroscope. Thus the vacuum tube synchronizing equipment makes unnecessary costly high-voltage transformers which have been almost universally used for synchronizing in the past.

The paper describes the commercial apparatus, gives equations pertaining to the vacuum tube amplifier and shows calculated and measured characteristic curves.

THE increasing number of power system interconnections makes synchronizing of high-voltage lines almost a necessity. Potential transformers for 110 kv. and above which have been almost universally used for synchronizing are costly. A new method of obtaining transformation from a high voltage to a low voltage by means of a simple capacitance, the power amplification of this controlling potential to an appreciable amount of power, the utilization of the output from the amplifier for operating a rotating type of synchroscope makes possible, economically and practically, the almost universal adaptation of high-voltage synchronizing.

Description of Units

The vacuum tube synchronizing apparatus as developed for commercial service consists of the following units:

a. Capacitance transformer bushing.
b. Outdoor Amplifier.
c. Indoor Amplifier and Power Supply.

Capacitance Transformer Bushing

Bushings equipped with capacitance transformers. (Fig. 1.) are of the regular flange-clamped oil-filled porcelain design similar in external appearance and construction to the standard line of General Electric Company's oil filled bushings. This added feature does not in any way affect the normal functions of the bushing when it is used with power apparatus. Where power apparatus bushings are not available and it is desired to use such a bushing, it may be mounted in a separate tank and installed in any convenient place, either indoor or outdoor. The capacitance transformer enables these bushings to be used with vacuum-tube equipment in place of instrument potential transformers for synchronizing.

The necessary voltage for the grid-filament circuit of the amplifying tube is obtained from a high-capacity condenser within the bushing. This capacity is in series with the bushing capacity, the total line-to-ground potential of the system being impressed across both. The voltage obtained across either condenser is inversely proportional to the capacity. The secondary potential is approximately 35 volts and therefor a relatively high-capacity condenser is employed. This high-capacity condenser consists of two layers of thin copper sheets separated by a treated paper dielectric and all wound on a herkolite cylinder. The outer layer of copper is grounded to the ground sleeve and a soldered connection to the inner copper layer is brought out through a terminal fitted in the ground sleeve. As shown in cross-section drawing, Fig. 3, this terminal

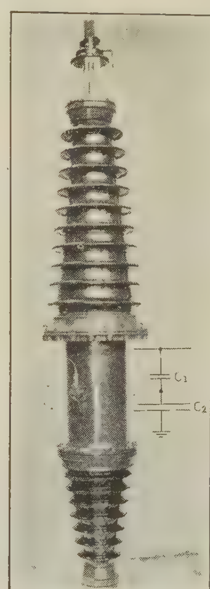

Fig. 1—132,000-Volt Bushing Equipped With Capacitance Transformer Showing Flexible Lead and Schematic Diagram of Connections

is encased by a metal housing to prevent exposure of any live metal.

Outdoor Amplifier

The outdoor amplifier consists of a PT-210 power tube with its associated filament transformer and bias resistors mounted in a steel weatherproof box. This unit is a complete single-stage amplifier. The voltage obtained from the capacitance transformer is impressed on the grid of the tube and the output delivered to the primary of the interstage transformer which is located on the indoor amplifier panel.

1. Both of the General Electric Co., Schenectady, N. Y.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Feb. 13-18, 1928. Complete copies upon request.

The secondary potential from the capacitance transformer is divided by means of a 600,000-ohm potentiometer so that 17½ volts are delivered to the grid of the tube. The amplification constant of the PT-210, and the ratio of the interstage transformer are such that

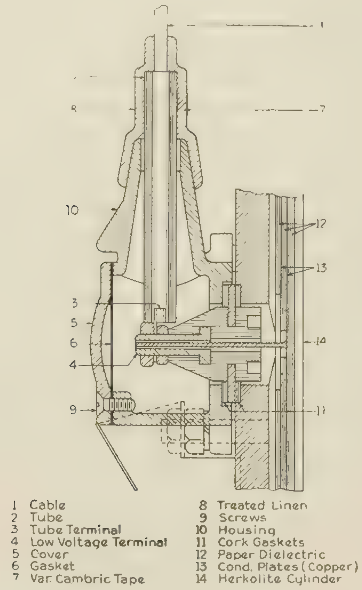

Fig. 3—Cross-Section Drawing Showing Method of Bringing out Terminal from Capacitance Transformer

the voltage applied to the grid of the second stage of amplification on the indoor panel is 35 volts. The potential from the capacitance transformer cannot be successfully applied directly to the grid of the

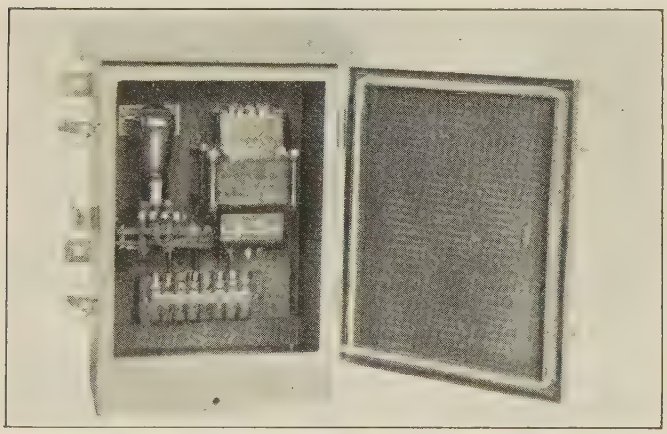

Fig. 4—Single Unit Outdoor Amplifier

second-stage amplifier tube since the d-c. grid current of this tube with normal negative bias is sufficient when flowing through the 600,000-ohm resistance across the low-voltage terminals of the capacitance transformer to alter the effective bias voltage so that the tube operates on an undesirable portion of its characteristic curve. A photograph of a single outdoor amplifier unit is shown in Fig. 4.

Two single outdoor amplifiers can be combined so as to make a double outdoor amplifier as shown in Fig. 5. Double units are usually used when synchronizing directly across oil circuit breakers as this facilitates mounting and reduces the number of necessary connections.

One capacitance transformer must be connected to the same phase on each side of the oil circuit breaker used for synchronizing, and connections made to the corresponding grids of the amplifier tubes. These units are preferably mounted near the capacitance transformers in order to reduce stray capacity effects across the secondary side.

Indoor Amplifier and Power Supply

The indoor amplifier is mounted on a panel of standard switchboard design. It is intended for mount-

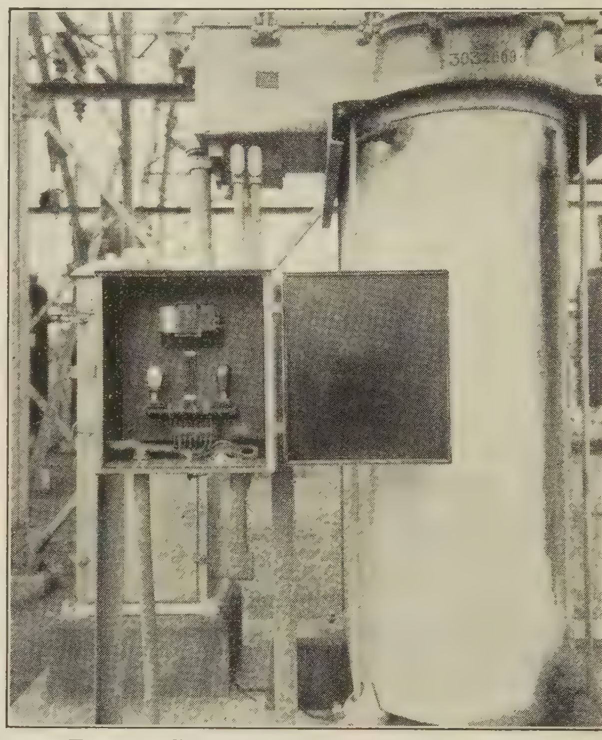

Fig. 5—Double Unit Outdoor Amplifier

ing alongside of the main switchboard, although it can be placed in any other convenient location in the station. A voltmeter for indicating the plate voltage to the tubes, a rheostat in the field circuit of the plate and bias voltage generators, and a fused switch for opening the voltage supply circuit to the motor-generator set, are located on the front of the panel.

On the back of the panel is mounted two separate single-stage power amplifiers requiring two PR-11A tubes. The undistorted power output which can be obtained from one of these tubes is approximately 10 volt-amperes. The grid of each tube receives its excitation through the interstage transformer from the outdoor amplifiers. An output transformer is connected in the plate circuit of each tube and supplies 110 volts for operating the synchroscope. The slight phase shift in voltage through the amplifier and trans-

former is corrected at 60 cycles by connecting the proper value of capacitance load across the secondary terminals of the output transformer. A metal grill is provided for covering the apparatus mounted on the back of the panel. The plate connections are made under the grill which eliminates any exposed high-voltage circuits.

All power for operating the vacuum-tube equipment is obtained from a small four-unit motor-generator set.

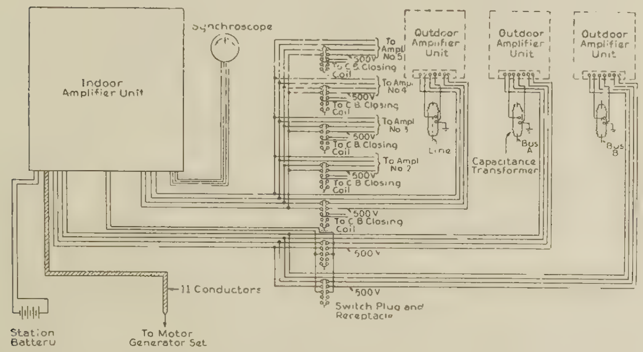

FIG. 7—SCHEMATIC LAYOUT FOR SYNCHRONIZING BETWEEN DOUBLE BUSES AND A NUMBER OF INCOMING LINES

The power supply for operating the set can be taken from the station battery or any other suitable voltage source. An automatic starter is located on the indoor panel which puts the motor-generator set in operation, as soon as the control circuit is closed, by the insertion of the synchronizing plug in the proper receptable in the switchboard.

The synchroscope is a 7½-in. diameter instrument, giving the usual indications of fast, slow, and synchronism. The synchronism indicator is mounted on a

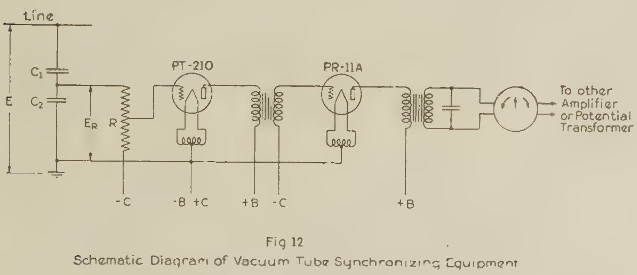

FIG. 8—SCHEMATIC DIAGRAM OF VACUUM-TUBE SYNCHROSCOPE EQUIPMENT

swinging bracket at the end of the switchboard in a substation. On the adjoining bracket is a synchronism indicator operated from potential transformer which in this experimental installation was used to check the operation of the vacuum-tube-operated synchroscope. This installation has been in daily service for over a year, proving its simplicity and reliability in actual service.

APPLICATION

The construction and operation of the synchroscope equipment is such that it is easily adapted for any number of incoming lines. When synchronizing is to be accomplished between a number of incoming lines and double buses, each incoming line must be equipped with a capacitance transformer, but it is necessary to use only one capacitance transformer for each bus.

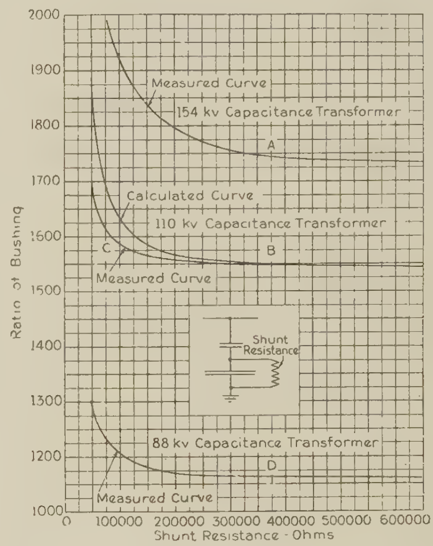

FIG. 9—RATIO CHARACTERISTICS OF CAPACITANCE TRANSFORMERS

Such an arrangement is shown in Fig. 7. The act of synchronizing, using the vacuum tube equipment, is exactly the same as when potential transformers are used. Thus, the operator inserts the synchronizing

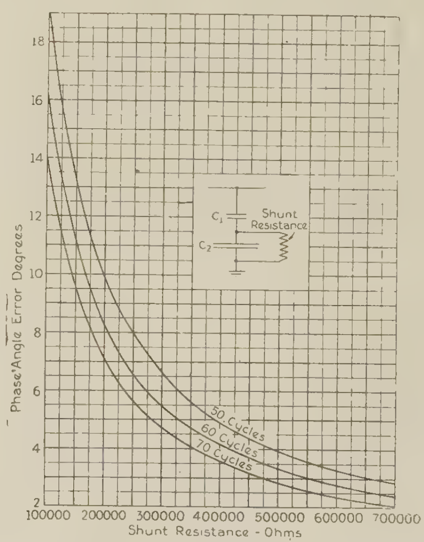

FIG. 10—PHASE-ANGLE CHARACTERISTICS OF CAPACITANCE TRANSFORMERS

plug, which automatically places the tube apparatus in operation, causing the synchroscope to revolve in the usual manner.

It is of importance to note that one winding of the synchroscope may be excited from a potential trans-

former and the other winding excited from the vacuum-tube amplifier without upsetting the phase relations on the synchroscope. A number of such installations have been made.

The life of the vacuum tubes is relatively long and from records of test data should be about 10 years of service operating on an average of 15 min. each day. Thus the maintenance of the apparatus is reduced to a very low degree.

Theory and Characteristics

The capacitance transformer has a constant ratio and zero phase-angle shift with varying frequency and voltage, providing there is no external circuit connected to it. When the potential of the capacitance transformer is applied to the amplifier, a resistance (R, Fig. 8) and the tube input impedance are connected in parallel with capacity, C_2. The tube impedance at 60 cycle is very high as compared with the impedance of either C_2 or R and can be neglected. The relation

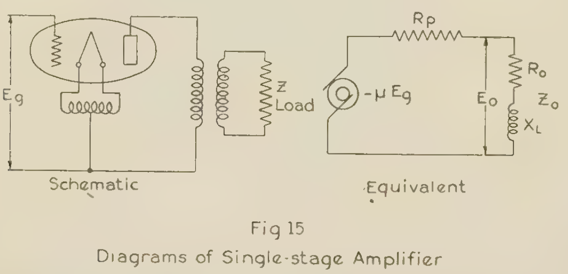

Fig. 11—Diagrams of Single-Stage Amplifier

between $\dot{E}_R$ and $\dot{E}$ is expressed by the following equation:

$$\dot{E}_R = \dot{E}\left[\frac{j\,\omega\,C_1\,R}{1 + j\,\omega\,R\,(C_1 + C_2)}\right] \qquad (1)$$

in which $\omega = 2\,\pi\,f$ and the other symbols refer to Fig. 8. Both the voltage ratio and the phase-angle shift of the capacitance transformer, and resistance combination can be obtained from this equation.

This equation shows that the voltage ratio $\dfrac{E}{E_R}$ is independent of voltage, but varies with frequency and resistance. A numerical example will show the magnitude of these variations. A particular 110-kv., (63.5-kv. line-to-neutral), installation has the following constants; $C_1 = 0.000050\ \mu$ f, $C_2 = 0.00772\ \mu$ f, and $R = 600{,}000$ ohms. The variation of voltage ratio with resistance is shown by the curves B and C, Fig. 9. The calculated curve B checks the measured curve C very closely. These curves show that the voltage ratio does not appreciably change with a considerable decrease in resistance. Therefore, the ratio is independent of leakage change within the capacitance transformer, which measurements show to be approximately 100 megohms or more. The ratio of the capacitance transformer mentioned above is 1543 at 60 cycles. At 50 cycles the ratio is increased 0.05 per cent and at 70 cycles it is decreased only 0.04 per cent; hence the ratio may be considered independent of frequency.

There is a phase shift through the capacitance transformer when a resistance is connected across

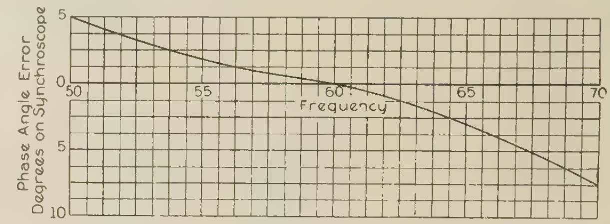

Fig. 12—Synchfoscope Characteristic

One winding exciter from potential transformer
One winding exciter from vacuum tube amplifier

it, and this phase shift is dependent on both resistance and frequency but is independent of voltage. A curve computed from equation (1), showing the variation of this phase-angle change with resistance, is given in Fig. 10. Thus 600,000 ohms gives a phase-angle shift of 2.75 deg., 500,000 ohms, 3.3 deg., and 700,000 ohms, 2.4 deg. at 60 cycles. At 70 cycles and 600,000 ohms, the phase-angle shift is 2.4 deg. At 50 cycles the shift is 3.3 deg.; that is, the secondary voltage E_R leads the line-to-neutral voltage a small amount due to resistance load, and changes slightly with change in frequency.

The vacuum tube amplifier, which is used to supply the power to the synchroscope, has characteristics which affect the over-all operation of the equipment. The complete theory of a vacuum tube amplifier is beyond the scope of this paper, but an approximate theory will be developed to show its general operation. The schematic diagram and the equivalent diagram of the a-c. circuits of a single stage of transformer-coupled

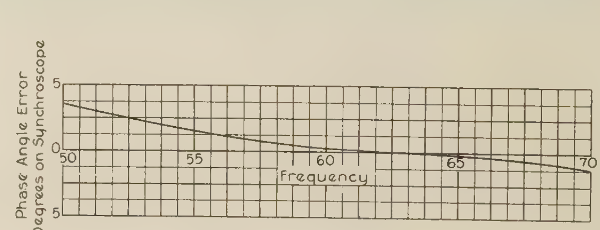

Fig. 13—Synchroscope Characteristic

Excited from vacuum tube amplifier

amplification is shown in Fig. 11. The expression for $\dot{E}_0$, the load voltage, can be written:

$$\dot{E}_0 = -\,\mu\,\dot{E}_g\,\frac{\dot{Z}_0}{\dot{Z}_T} \qquad (2)$$

where

$\dot{E}_o$ = Load voltage referred to primary of transformer
μ = Amplification constant of tube
$\dot{E}_g$ = Applied grid voltage

$\dot{Z}_0$ = Load impedance referred to primary of transformer

$\dot{Z}_T$ = Total impedance of tube plate circuit.

The negative sign of the right side of the equation indicates a phase shift of 180 deg. through the tube itself, but since transformer coupling is used, this phase shift can be corrected by proper choice of transformer connections.

Equation (2) shows that the voltage ratio of the amplifier is dependent on the tube-plate impedance and load impedance. The load impedance is independent of applied voltage and in a properly designed amplifier the tube-plate impedance is independent of applied grid voltage. Under these conditions, the voltage ratio through the amplifier is constant for varying voltage input. Also, since these two impedances are independent of voltage, the phase shift through the amplifier is constant with varying voltage.

The effect of frequency changes on the operation of the amplifier can also be predicted from equation (2). This equation may be rewritten in the following form:

$$\dot{E}_0 = -\mu \dot{E}_g \left[\frac{R_0 + j X_L}{R_1 + j X_L} \right] \qquad (3)$$

where $R_1 = R_0 + R_p$; hence it is always larger than R_0. As X_L increases with frequency, the fraction on the right side of equation (3) increases, but approaches unity as a limit. This shows that the over-all amplification of the stage increases with frequency, but approaches a definite limit. The percentage increase in voltage is less, however, than the percentage increase in frequency.

The phase angle between E_0 and E_g can be obtained from equation (3) and is given by the following expression:

$$\theta = \tan^{-1} \frac{X_L}{R_0} - \tan^{-1} \frac{X_L}{R_1} \qquad (4)$$

Now $R_1 > R_0$

hence $$\frac{X_L}{R_0} > \frac{X_L}{R_1}$$

and $$\tan^{-1} \frac{X_L}{R_0} > \tan^{-1} \frac{X_L}{R_1}$$

The angle θ is therefore positive, and E_0 leads E_g by this angle. As the frequency increases, the two ratios X_L/R_0 and X_L/R_1 increase in proportion and a consideration of the anti-tangent functions will show that the angle θ decreases with an increase in frequency.

The above discussion explains the general operation of a vacuum-tube amplifier with inductive reactance in the load. If, however, the secondary of the transformer is loaded with capacitance until the reactive component of the load impedance is capacitive, then the term $j X_L$ in equations (3) and (4) is replaced by $-j X_0$. Under this condition it can be shown in the same manner as before that with an increase in frequency the amplification of the stage decreases, the phase shift through the stage increases and is always negative.

The commercial apparatus utilizes a two stage amplifier. Now, if θ_T represents the total phase angle shift from phase voltage of line-to-voltage across synchroscope, θ_1, the shift through the capacitance transformer, θ_2, the shift through the first stage of amplification and θ_3, the shift in the second stage then

$$\theta_T = \theta_1 + \theta_2 + \theta_3 \qquad (5)$$

By connecting sufficient capacitance in parallel with the synchroscope, the angle θ_3 can be made negative and equal to θ_1 plus θ_2, and hence, the total angle shift is zero. With a given capacity, this condition exists for one frequency only, and the value of the capacity in the commercial equipment is so chosen as to compensate at the operating frequency.

The curve of Fig. 12 shows the angular error in position of the synschroscope when using the amplifier on one side and a potential transformer on the other. This is equivalent to the shift through the amplifier as the angular error due to the potential transformer is negligible. The maximum error within the range of 50 to 70 cycles is only seven degrees, or only slightly larger than one minute on the dial of a clock. The device is therefore satisfactory when used in combination with a potential transformer.

Fig. 13 is a curve showing the angular error when two amplifiers are used. In this case the maximum error is reduced to 3.3 deg. which is scarcely discernable on the synchroscope.

The authors wish to acknowledge the help given by Mr. E. D. Eby and Mr. T. S. Farley, who kindly assisted in obtaining the information for this paper.

URGE SIMPLER LIGHTS TO AID AUTO DRIVERS

Simpler automobile headlights requiring no adjusting or dimming were urged by the Motor Vehicle Lighting Committee of the Illuminating Engineering Society at a meeting held Jan. 11, 1928. Complicated lighting systems, which properly operated, provide perfect lighting conditions from every standpoint are not practical in the opinion of the majority of engineers present.

The headlight of the future should not be intended to provide lighting conditions but only to give adequate illumination with minimum attention from driver.

More stringent laws regarding headlights were suggested by E. C. Crittenden, Chief of the Electrical Division of the Bureau of Standards, who declared that a high percentage of accidents are caused by faulty headlights. He also urged the single-beam light, constructed so as to remain properly focused and adjusted without attention from the driver.

Colonel A. B. Barber, manager of the transportation department of the United States Chamber of Commerce, and W. D. A. Ryan, director of the illuminating engineering laboratory of the General Electric Company also spoke, Colonel Barber outlining the the present motor vehicle laws and restrictions and urging uniform motor laws for the entire country.

Abridgment of

132,000-Volt, Single Conductor, Lead Covered Cable

Introduction, Economics and Commercial Demand

BY P. TORCHIO[1]

Fellow, A. I. E. E.

Synopsis—*This paper, which describes the development of the oil-filled type of 132,000-volt cable, has for convenience been divided into four parts.*

In the first part the economic and commercial aspects of the development are discussed. It is pointed out that this type of cable permits direct interconnection with high-voltage overhead lines and it is felt that the satisfactory operation of the two lines which have been placed in service this year will be an indication that 220,000-volt cable can be constructed without material changes in the design.

The theory and design of the cable are completely developed in the second part. Particular reference is made to the effect on the dielectric of occluded gas and the method of eliminating trouble from this source in the oil filled type is described.

The third part relates to the manufacture, inspection and testing of the cable and equipment. The tests showed that the electrical constants of the cable were substantially unchanged by the normal temperature cycle.

The installations at New York and Chicago are described in the fourth part. Inspection, indication of oil leaks, cable and joint repairs are discussed. The replacement of a length of the New York cable, which developed a leak in the sheath, is covered in detail.

* * * * *

WHILE the power generated from local plants in heavy centers of industry and population is distributed locally at about 13,000 or 25,000 volts, system interconnection lines and long-distance transmission lines require considerably higher pressures in the order of 66,000, 132,000 and 220,000 volts.

In most situations of heavily built-up centers, it has been impossible in the past to tie the higher voltage lines directly to the distributing stations and substations, and recourse has been made to underground cable lines of 33,000 45,000 and 66,000 volts connecting to the higher voltage overhead lines through transformers located at substations on the outskirts of the city. One of the principal aims of the design of the new type of cable, which by one step doubles the highest underground operating voltage used heretofore, is to do away with the seoutside intermediate substations by bringing the higher voltages directly to the ultimate distributing centers. The economic and operating advantages thereby obtainable are savings of intermediate substations, transformers, switchgear nda attendance, reduction in number of underground cables, savings in synchronous condensers, increased efficiency, improved regulation and improved stability of parallel operation of local plants with the outside sources of power. The final relative values of these savings will not be available until we have secured from actual experience the relative carrying capacity of the oil-filled cables in contrast with the ordinary type of cables with solid insulation.

The theory of the oil-filled cable is that through its collapsible oil reservoirs it responds readily to volumetric changes in oil and cable due to temperature changes. In this manner, the whole cable is kept constantly filled with oil under pressure both in the hollow core of the conductor and throughout the surrounding insulation. The unique advantage of this type of construction, therefore, is that should the lead sheath be expanded or distorted, or the internal elements of the cable be displaced by temperature variation or other causes, the spaces thus formed will be immediately filled with oil, while in a solid insulation type voids would be formed, causing ionization and ultimate failure. It is thus evident that this new type of cable should be able to operate safely over a much larger range of copper temperature and therefore of load, than a solid insulation type, even if the latter is operated only at 66,000 volts or less. In this expectation we are confirmed by the original installation of this type of cable made in Italy three years ago, which consisted of about 2000 ft. of line connected in series with a 130,000-volt overhead transmission line more than 100 mi. long. This cable, which was 50 sq. mm.; about 100,000 cir. mils, in cross-section, has never given the slightest trouble though carrying currents of 250 amperes per phase, a current density which would be absolutely impossible with the solid type of cable even if operated at 25,000 volts or less.

The Chicago 132,000-volt underground cable line is a direct application of the plan of connecting a generating plant in the city to an outside 132,000-volt line six miles away.

The New York 132,000-volt cable is, for the time being, a large-capacity, 12-mi. length transmission line supplying the large county of Westchester in the state of New York, but it will, in future, serve also to interconnect with outside sources of power supply.

The Chicago and New York installations were placed

1. The New York Edison Company.

Presented at the Regional Meeting of District No. 5 of the A. I. E. E., Chicago, Ill., November 28-30, 1927. Complete copies upon request.

in operation, respectively, on June 2nd and August 9th, of this year, and have since operated without electrical trouble.

The manufacturers feel that should these two 132,000-volt cable lines continue to prove satisfactory in operation, 220,000-volt cable can be constructed without material changes in the design of cable, joints and accessories.

The next year's experience of the large New York and Chicago installations appears now almost certain to prove satisfactory, in which event this great advancement in the art will have made available to the industry, confronted with unprecedented volume of growth in its demand for power, means not heretofore available for transmitting hundreds of thousands of kilowatts economically and directly to and from centers of heavy population and outside supervoltage overhead lines.

In the following chapters, the manufacturers and the users are presenting a complete description of all the phases of work involved in the design, manufacture and installation of this radically novel type of cable.

Theory, Design, and Development of the 132,000-Volt Cable

BY L. EMANUELI[2*]
Non-member

General. It is well known and recognized that one of the principal reasons of failure in high-tension cables is the presence of gas bubbles and films in the dielectric, some of these gas occlusions being left in the insulation during the construction of the cable and some being formed later during the operation of the line.

This is due to many facts. First, the vacuum applied to the cable before impregnating it with insulating compound is not generally perfect. Second, the insulating compound carries in solution a great volume of gas, part of which is set free while the compound is passing through the paper during impregnation. Third when the lead sheath is applied to the cable, the cable is still rather warm and the subsequent thermic contraction of the compound when the cable cools down causes further voids. Empty spaces are also created when the cable is coiled on the reels and during handling.

When the cable is in operation, another important phenomenon takes place. The insulating compound is warmed up and increases in volume when the cable is loaded and this first compresses the gas in the dielectric and then expands the lead sheath. As the lead is more viscous than elastic, after a subsequent cooling the total amount of void space within the dielectric is greater than before installation by an amount proportional to the load carried.

For example, in a 66,000-volt cable the contraction which follows an increase of temperature in the copper of 35 deg. cent. causes a volume of seven gal. per mi., (16 liters per km.), to be emptied of compound.

The pressure which may take place in a cable when loaded and which forces out the lead tube has been found by actual measurement to be in the neighborhood of 90 lb. per sq. in.

Seasonal temperature variations produce the same effects.

Where is it that these empty spaces are formed? In a general way, we can assume that they are produced at the points where the paper is less compact in the wrinkles in the space between the lead and the insulation, especially where the lead is expanded due to bends or handling and, for three-conductor cables, in the spaces between the insulated conductors and the fillers.

This may be explained when one thinks that the surface tension of the compound has a tendency to fill up first the smaller cavities, thus leaving empty the larger ones.

In addition to this, the compound has a tendency to migrate to the lowest points of the cable and this migration is greater the lower the viscosity of the compound.

This irregularity in the distribution of the gas cavities is one of the principal causes of the many uncertainties in the results obtained in the laboratory and during operation, and makes it impossible to fix an exact figure for the permissible value of the ionization as a function of the working voltage.

The failure of all the previous attempts made to explain theoretically the breakdown voltage on a sample of cable, in connection with the electric gradient in the insulation, can probably be attributed to the presence of gas occlusions and to their irregular distributions, and perhaps the theory which gives the breakdown voltage as a function of the minimum gradient and not of the maximum, is not to be completely discarded, the minimum gradient being near the lead where the empty spaces, at least for a single-conductor cable, have a greater tendency to be formed.

If the empty spaces due to the thermic contraction of the compound were formed uniformly in the insulation, in small units, the troubles produced by their ionization would be very small. A step toward this point has been gained by the cable manufacturers by wrapping the paper on the conductors as uniformly as possible, and avoiding wrinkles and registration of the layers.

It is also evident that the greater the thickness of the

2. Societa Italiana Pirelli.

*Acknowledgment and thanks are made here to Dr. E. Sacchetto who has given his assistance in the first experiments on the oil filled cable and in the installation of the Brugherio cable, Mr. E. Sesini who has assisted in the theoretical design of the cable and accessories and Mr. M. Puritz who, with Mr. Sesini, has directed all the delicate operations of installation and impregnation of both the New York and Chicago lines. Acknowledgment is also made of the valuable assistance and cooperation rendered by the engineers of the General Electric Company and of the New York and Chicago Companies during all these latter operations.

insulation, the smaller is the possibility of avoiding such empty spaces during construction. In addition to this, if the contraction of the insulating compound should be such as to distribute uniformly and in small units the empty spaces which are formed, then the quality of a dielectric would be independent of its thickness; but, due to their localized formation as a consequence of capillarity and drainage, the probability of leaving the big empty spaces is greater the greater the volume of the dielectric, and accordingly of the amount of oil subject to volumetric change. We can assume, therefore, that an increase in the insulation thickness does not produce a corresponding improvement in operating performance; and the cable manufacturers know this very well.

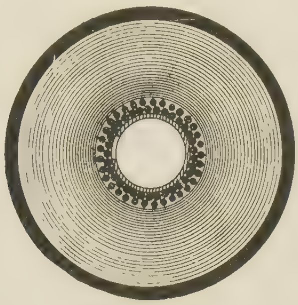

Fig. 1—Hollow Core Cable

All these difficulties and uncertainties would not have allowed the design of a 132,000-volt cable of the usual type with any probability of success and the results which may have been obtained in the laboratory and in the field on short lengths of cable would have been practically worthless due to variations in the distribution of the gas occlusions.

It must also be considered that the experience gained on a large scale on existing cables is limited to a voltage which is only about one-half of 132,000 volts. It was with the idea of avoiding all these uncertainties, eliminating gas occlusions, as much as possible and especially the ones which are formed by temperature variations, that the design and construction of the oil-filled type of cable was carried out.

The principle is very simple and consists in having the cable connected to a reservoir which will receive the oil pushed out during the thermic expansion and give it back to the cable during the contraction. To obtain this action, it is necessary to have inside the cable a passage which connects the reservoir with every point of the dielectric. This feature can be obtained readily by stranding the copper wires of the conductor around a metal spiral, thus leaving a single central passage, see Fig. 1, or by shaping the lead sheath as shown in Fig. 2, thus making several longitudinal paths which can be connected to the reservoir. This eliminates the danger of formation of empty spaces due to the contraction of the oil.

The presence of a longitudinal path makes possible the evacuation and impregnation of the cable from both ends after it has been leaded. On account of its small volume, laboratory pumps can be used and a very high vacuum reached. In addition to this, a special process has been worked out to purify the oil from the gases in solution, before impregnating the paper.

In this way it is possible to obtain a cable practically without any occluded gas from the start and also to maintain it in such condition during operation.

An experiment on a cable of the type given in Fig. 1 was made early in 1918 and the results were quite surprising. The life tests gave results far better than those on usual cables and it appeared immediately that the importance of a perfect construction of the cable as regards wrinkles and compactness of the paper, could be regarded as secondary.

It is important to remember that in a cable made in the usual way, the breakdown voltage is very high if the voltage is increased quickly and does not give no light on the punctures which happen in operation at a voltage generally equal to, or slightly higher than, the operating voltage. If the tension is applied for several hours, the breakdown voltage is considerably smaller, and the longer the time of the test, the lower the breakdown voltage. It is not difficult, for instance, to get a breakdown voltage on a short sample, after a few seconds, which is five times greater than that found after several hours of application of voltage.

In the oil-filled cable these differences were found to be much smaller, and as the instantaneous breakdown voltage is equal to, if not greater than, that on usual cables, the breakdown voltage after several hours is more than doubled. This permits increasing the operating gradient of the cable and the use of only a small thickness of insulation.

Fig. 2—Slotted Sheath Cable

Another advantage over other cables of the usual type is to have much smaller dielectric losses at high temperatures because it is possible to use a very fluid oil with very small power factor, as the danger of migration of the compound is avoided.

For several reasons a field test of this new type of cable was not made on a large scale until the end of 1923 when a line of three cables of 100,000-cir. mil (50 sq. mm.) copper area, 670-mil (17-mm.) insulation, each

2000 ft. (610 m.) long, with six joints, was installed at Brugherio near Milan, Italy, connected to an overhead line about 100 mi. (160 km.) long. In the beginning the cables did not carry load, but in 1924 they were put

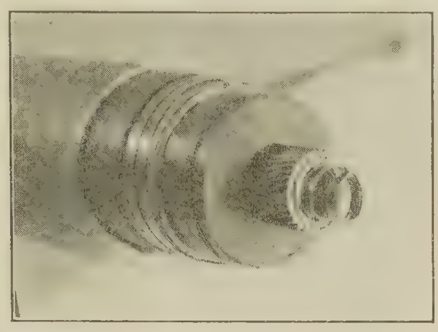

Fig. 3—Illustration of 132-Kv. Cable

in series with the line and a load up to 250 amperes per phase was carried without any trouble for two and one-half years.

The electrical problem of the construction of a cable

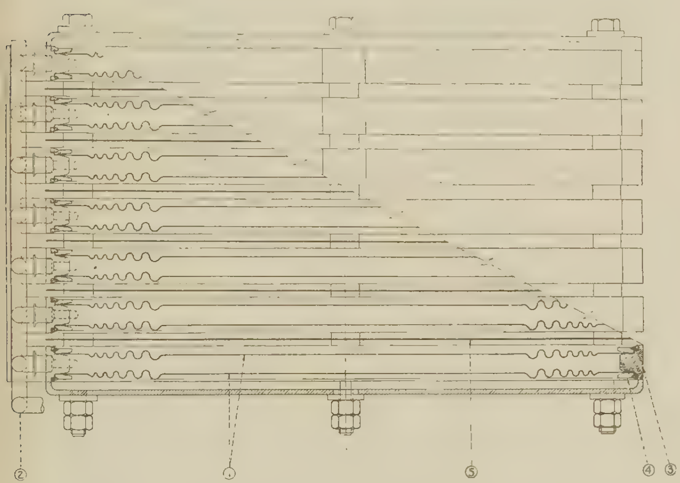

Fig. 4—Feeding Tank

for 132,000 volts was in this way solved quite satisfactorily but several mechanical problems, especially complicated for lines of long length and with large differences of level, remained to be studied.

The theoretical and practical problems which had to be solved before the liquid oil filled cable could be made a practical success are discussed in detail in the complete paper but must be omitted here because of lack of space, which permits only a brief description of the cable itself and the principal accessories.

Cable Design. The cable installed in New York and Chicago is shown in Fig. 3. The conductor of 600,000-cir. mil section is made up of two layers of copper wires, stranded over a spiral of hard drawn copper tape, leaving a clear diameter inside the spiral, of ¾ in. The insulation thickness is 23/32 in., made up of wood pulp paper in three different gradations, depending upon the porosity. A mineral oil a little more viscous than that used in transformers is used for impregnating the cable.

Description of the Special Accessories: Feeding Tanks. The principal requisites of the oil tanks are that the oil inside should always be practically at atmospheric pressure, independent of the volume of oil present in the tank, and that it should be in no way in contact with the surrounding air.

The problem has been solved using collapsible reservoirs made up with thin metal walls, which are easily deformable. In such a way the oil is not in contact with the air and yet acts with regard to the pressure as if it were contained in an open reservoir.

Fig. 4 gives the drawing of a feeding tank.

Seven separate cells, each with collapsible walls, *1*, are connected in parallel to a common manifold, *2*. Each cell is made up from a ring, *3*, on which two corrugated diaphragms, *1*, are soldered and kept in

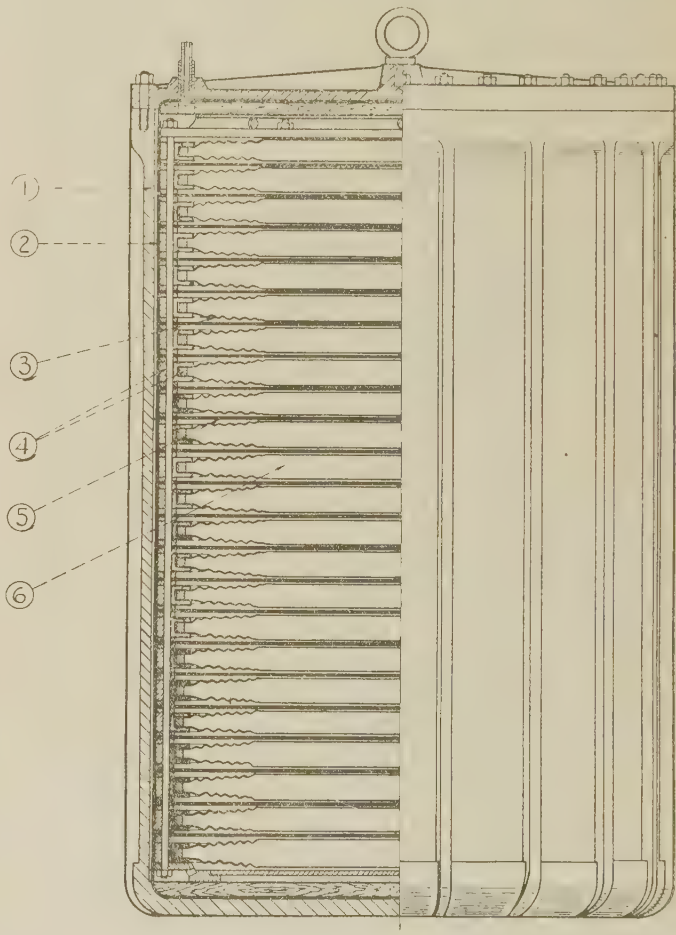

Fig. 5—Pressure Tank

place by a ring, *4*. The corrugation allows the plates to move under expansion or contraction.

Two standard types of tanks were adopted, one with seven cells, as given in Fig. 4, called *S*-7, and one with 11 cells called *S*-11.

Each cable of a section was fed by two or more of these tanks, paralleled by means of valves and manifolds.

Pressure Tanks. As before stated, the characteristic

of this type of tank, Fig. 5, is to have a certain number of collapsible air-tight cells, *3*, full of gas, separated by heavy plates, *5*, contained in the tank, *2*, which is filled up with oil. The outside tank, *1*, is able to withstand the maximum pressures given by the oil of the section during expansion.

Each cell is perfectly tight and is filled with an inert gas, *6*, especially selected for the purpose.

Stop-Joints. As has been explained in the design of the cable, each section is connected electrically to the next one by means of a special joint called a stop-joint, which cuts the oil communication between them. (See Fig. 6). The stop-joint consists essentially of a cylindrical tank, *1*, full of oil, *2*, which contains two inserted procelain terminals, *3*, in a *V* arrangement.

The end cables of each section terminate in these potheads, which are electrically connected at the lower part. As for the pressure tanks, the outer tank is of

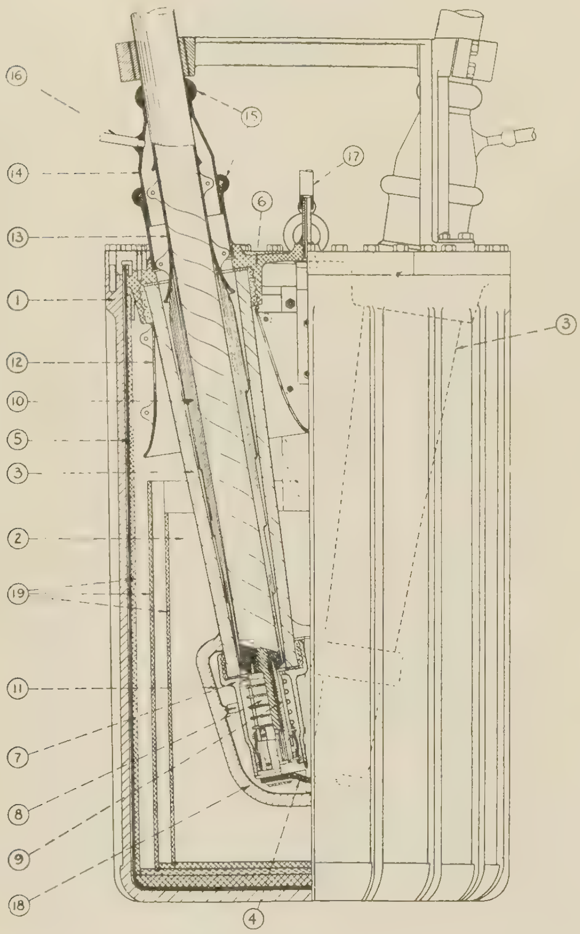

Fig. 6—Stop-Joint

suitable thickness and has a lining, *5*, hermetically sealed to the upper cover, *6*. The terminal's insulators are cemented at the upper end to the cover and are provided at the lower part with two cemented metal caps, *7*; the tightness of the seams is guaranteed by composition cork gaskets.

The two caps are electrically connected by a flexible connection, *4*, and carry on the inside a set of brushes, *8*, for the contact with the connector, *9*, which is soldered at the end of the cables. The two lower caps and the connection, *4*, are screened by a metal box, *11*, so as to have a good distribution of the electric field; for the same reason the insulators are provided at the upper end with electrostatic controls, *12*. The metal screen,

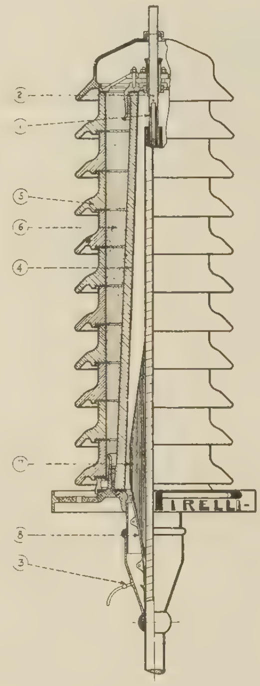

Fig. 7—Pirelli Terminal

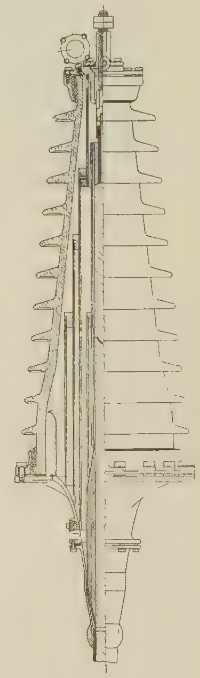

Fig. 8—General Electric Terminal

11, is reinforced electrically with paper wrappings, *18*, and the discharge path to the case is protected by insulating barriers, *19*. The two end cables, after being reinforced in the field with paper wrappings, *10*, and provided with electrostatic controls, *13*, are slipped inside the insulators so that their connector, *9*, is wedged between the brushes, *8*, and the lead sheath of the cable is soldered to the cover by means of metal sleeves, *14*. As a matter of fact, the stop-joint tank is *raised* from a pit in the manhole up to its final position so that the cables slip inside the insulators. The only wipes to be made in the field are those at *15*. The oil is fed to the cables through a pipe, *16*, which is connected to the reservoirs at the feeding end of the section.

The oil chamber, *2*, inside the stop-joint, is connected in the field through the pipe, *17*, to the terminal at the higher pressure, each terminal being at the pressure given by the height of the reservoir of the section to which it is connected. In this way, the oil in the tank is always at the same or at a higher pressure than the oil inside each of the insulators and the porcelain is subjected only to compression.

Terminals. Each manufacturer supplied the terminals to be used on his own cable. The general construction of each of the two types is shown in Figs. 7 and 8.

Manufacture, Inspection and Testing of the 132,000-Volt Cable

By Wallace S. Clark[3]
Associate, A. I. E. E.

There are certain novel features in the manufacture of the cable which are, we hope, of sufficient general interest to warrant their introduction here.

In order to secure a central passageway through the conductor, a spiral of hard-drawn copper strip was formed and the wires composing the conductor proper were stranded around this. Special machinery was installed to make this spiral and special precautions had to be taken in stranding the individual wires around it, the inner layer of wires being dented to give free circulation of oil.

The wood pulp paper used in forming the insulation wall was of three different thicknesses and varied in density, the thinnest and densest paper being put next to the conductor where the electrical strains are greatest; then the intermediate paper, and on the outside, the least dense and thickest paper.

After the core was completed, a radical departure from ordinary practise occurred. The insulated core had the first lead sheath applied, was wound on a reel and heated by immersing it in a steam bath. The ends of the cable were sealed and insulated leads were brought out through these seals.

The exhaustion of the heated cable core with vacuum pumps was the next step.

Measurements of the power factor of the cable and the insulation resistance between the conductor and the lead sheath during the evacuation were taken periodically. The particularly interesting point in this process is that if the lead sheath has any imperfections in it, moisture (steam) will naturally be sucked in through these imperfections, and the electrical measurements made will indicate that this is happening. This makes it improbable that there should be undetected faults such as porous spots or pin-holes in the lead.

When the desired electrical measurements were obtained, oil, which previously had been given a special treatment for purification and for the removal of all absorbed gases,—(ordinary transformer oil will absorb from 15 to 20 per cent of its own volume of air),—was admitted to the central core very slowly, saturating the paper wall.

The cable was finally cooled down under oil pressure and when room temperature was reached, it was taken from the tank and was ready to test.

After testing, the ends were hermetically sealed and the cable was ready to receive its armor and outer jacket of lead.

The armoring consisted of wrapping the inner lead sheath with treated paper tape; next with a thin hard-drawn copper tape; then a second paper tape. The cable was then taken back to the lead press and leaded all over, and after removal of the oil, made ready for shipment on especially large bodied reels.

Tests. The specified tests were similar to those of the A. E. I. C. Specifications, and the principal ones were as follows:

a. Each reel of cable had to stand 175,000 volts, alternating current, for 15 min. between conductor and sheath.

b. Samples maintained at 0 deg. cent., freezing for two hours, were bent three cycles to 180 deg. around a drum having a diameter 15 times the diameter of the cable, and then withstood 225,000 volts, alternating current, for five minutes.

c. One full reel of cable from each 15,000-ft. lot was tested with 140,000 volts, alternating current, for eight hours.

d. The original specifications called for a test after installation of 140,000 volts, alternating current, for 15 min. between conductor and sheath. As it was impractical to secure transformers for this, special kenotron testing sets were provided in New York and Chicago, and the cable successfully tested with 300,000 volts, direct current, for 15 min.

The maximum power factor on any one section of cable at room temperature did not exceed ½ of 1 per cent, and the power factor at 65 deg. cent., maximum operating temperature, did not exceed 0.65 per cent. The difference in power factors, ionization, when measured at stresses of 20,000 and 95,000 volts, 28 and 132 volts per mil, respectively, did not exceed 0.2 per cent. The average figures were very much better than these.

In connection with the ultimate breakdown tests, which were performed on these samples after they had passed all the required voltage tests, it is interesting to note that comparing the breakdown tests with those made on General Electric cables of standard type without oil ducts and intended for maximum working pressure of 75,000 volts, and having only 1/64-in. thicker insulation, the short time breakdown voltages were about the same; but with long time tests at lower voltages, the oil filled cable far out-distanced the ordinary type.

Special Tests. Samples of cable were run 24 hr. at 225,000 volts, alternating current, without breakdown or injury. This was three times the working stress.

The five-min. breakdown on samples was about 400,000 and the one-hr. breakdown about 300,000 volts, alternating current.

One special test at Milan ran 30 hr. at 200,000 volts, after which the potential was raised to 260,000 volts, alternating current, and held for 20 hr. without failure.

A very interesting feature shown by the special tests was that a length of cable could be tested and the constants determined; then, after a heating and cooling cycle, be remeasured substantially without change in the results. This is one of the best guarantees of

3. General Electric Company.

minimum electrical deterioration which can be determined by test.

Duplication of manufacturing processes at Schenectady and Milan was secured through the freely offered assistance of the Pirelli engineers and the constant interchange of manufacturing data.

The general results at Milan and Schenectady showed good agreement, even though some of the Milan tests were made at 42 cycles instead of 60 cycles, and all tests exceeded the specifications by a large margin.

Installation of the 132,000-Volt Cable

By A. H. Kehoe,[4] C. H. Shaw,[5] J. B. Noe,[5] and
Fellow, A. I. E. E. Associate, A. I. E. E. Associate, A. I. E. E.
D. W. Roper.[6]
Fellow, A. I. E. E.

Location and Description of Route. In New York, the cable runs from the Hell Gate Generating Station of The Edison-United Companies, northward through the Borough of Bronx and up to the Dunwoodie Distributing Station, in the City of Yonkers, Westchester County, a total distance of about 12 mi. The feeder will be used to supply the rapidly growing area of Westchester County immediately north of New York City, having in mind also the possibility of its use in the future as a link in the supply of water power from the St. Lawrence district directly into the metropolitan area of New York.

In Chicago, the 132,000-volt feeder runs from the Northwest Generating Station of the Commonwealth Edison Company northward to the city line, a distance of about six miles where it is connected to 30 miles of overhead line, continuing northward to the Waukegan Station of the Public Service Company of Northern Illinois. The line thus serves as a tie between generating stations, and transmits power in either direction, as may be required. As may be seen from the line profiles in Fig. 9, there is a difference in level of 285 ft. between the high and low points in New York, compared with 27 ft. in Chicago, excluding the river crossing. This difference in topography and grades made necessary radical differences in sectionalizing the line and the location and operation of the tanks supplying oil to the cable.

In New York, the southerly half of the feeder cable was Pirelli make; the northerly half, General Electric. In Chicago, the cable for two phases was supplied by the General Electric Company, and that for the third, by Pirelli.

Conduit and Manhole Construction. In both New York and Chicago standard methods of duct construction were used. The manholes, however, were made about 50 per cent larger to accommodate the larger joints and to give space for training the cables on large radius bends.

Towers. In order that sufficient hydrostatic pressure might be maintained on the oil inside the cable, it was necessary that the feeding reservoirs be elevated above the section of the line being fed. In Chicago, where the ground contour was practically flat, this result was secured by placing the oil reservoirs in towers located at the ends of the line and at two intermediate points. In New York, it was possible by taking advantage of the hills to obtain sufficient pressure with the reservoirs located in manholes, except at the two terminals of the line.

Oil from the feeding and pressure tanks is fed into the central core of the cable through lead pipes connected into the stop joints.

Cable Splices. While the manufacture of the cable at Milan and at Schenectady was practically identical, the standard joints were radically different, each

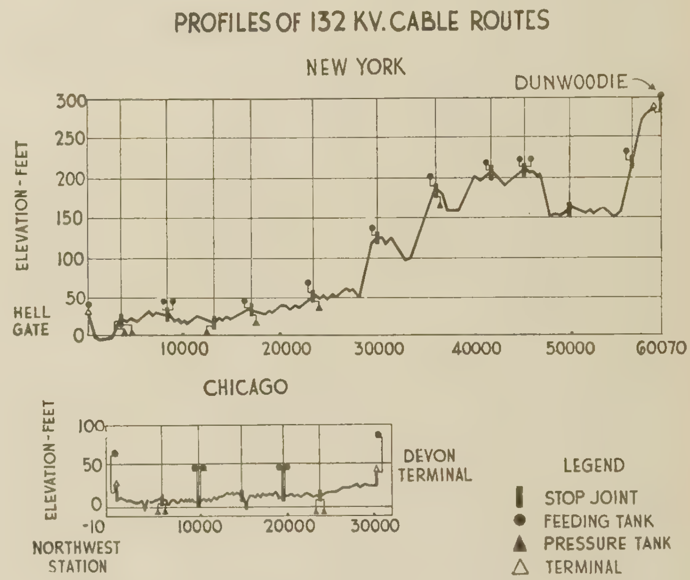

Fig. 9—Profiles of 132-Kv. Cable Route

manufacturer supplying the jointing material to be used in splicing his own cable.

The connectors for joining the hollow core cable and continuing the passageway for oil in the center of the cable through the joint are similar in the Pirelli and General Electric joints. In the center the connectors have a transverse hole closed by a screw so that any joint, before it is insulated, can be arranged to communicate directly with the oil passage in the center of the cable.

Pirelli Type. The chief characteristic of the Pirelli joint is that the insulating material in the joint is paper which has been previously dried and prepared in the factory. This paper is not impregnated, but is suface-treated to reduce the absorption of moisture which might be collected during the process of jointing.

Another distinct feature is that the original insulation of the cable, after it has been properly penciled, is covered with a thin oil silk tape to reduce seepage of oil between the joint insulation applied in the manhole and the original insulation in the cable proper, the

4. United Electric Light & Power Company.
5. The New York Edison Company.
6. Commonwealth Edison Company.

object being to evacuate and impregnate the insulation of the completed joint independently of the cable insulation.

The treated paper tape is applied by means of a special taping machine.

After the joint has been made up, the lead sleeve applied and the cable impregnated, the joint is heated by an electric heating pad, vacuum applied until all mositure is removed, after which oil is admitted to the joint.

General Electric Type. The General Electric joint is their well-known "stepped joint" type, the material of the insulation being a high-grade varnished cambric, hand applied. A copper sleeve is used, made up in two parts, telescoping in the middle. After the cable has been impregnated, the joint is evacuated, and filled with oil, no heating being required.

Cable Evacuation and Impregnation. The cable was impregnated one section at a time, the first step being to evacuate and fill the reservoirs with oil, after which the cable was put under vacuum by means of vacuum pumps connected at each provisional and stop-joint on the section. This evacuation was maintained for approximately 12 hr. for drawing out any gas or surplus oil in the core of the cable.

As shown on the profiles, there were many high and low points along a section of line; and slugs of oil were formed at the low points, while gas would collect at the higher points. A suitable test was made at the beginning of evacuation to determine the height of these slugs opposing vacuum between adjacent provisional joints. The maximum and average heights for the slugs were, respectively, 10 and 3 ft. This "slug" test served also as a check on the continuity of the cable core and connections and permitted a prompt discovery of leaks or stoppages.

After the initial 12-hour evacuation period, tests were made to determine if slugs of oil still existed in the low points of the line which would interfere with obtaining a satisfactory vacuum at all points of the section. After these tests proved satisfactory, the line was evacuated for approximately 36 hr. If a good vacuum was then maintained and no leaks occurred, treated oil was admitted to the line.

At the beginning of the impregnation of a section, oil was admitted to only one phase, the second phase being connected when the first was about one-third filled, from 8 to 24 hr. later, depending upon the flow of the oil and the contour of the section. The third phase was connected when the second was about one-third filled. Upon the arrival of the oil at each provisional joint, it was first drained off into test bottles for testing and then the oil was allowed to flow into the impregnating bottle until the flow reached a satisfactory value. After the pressure of the oil had become greater than atmospheric, the apparatus was disconnected and the joint closed.

Operation

There have been no electrical troubles from the time the cables were put into operation, June 2 for Chicago and August 9 for New York, to the time of writing, October 20; but there have been oil leaks which required repairs in stop-joint, gasket of pothead, joint wipes, pressure tanks, and lead jacket of cable section. In all cases, it has been possible to maintain the line in service until convenient to take it off for repairs.

The maximum load on the lines has been about 45,000 kv-a. The manufacturer's guarantee included a maximum allowable copper temperature of 65 deg. cent., a maximum power factor at that temperature of 1.25 per cent and a carrying capacity of 91,000 kv-a. The insulation of the cable as delivered, however, had a power factor of 0.5 per cent which permits an increase in the rating under identical field conditions to 98,000 kv-a.

The charging current of the underground line is 2400 kv-a. per mi., or about 25 times the value for a 300,000-cir. mil overhead line of the same voltage. The underground installation in Chicago is equivalent to a synchronous condenser of about 14,000-kv-a. capacity and the corresponding figure for New York is 28,000 kv-a.

Inspection and Signaling. Special equipment, processes, and plans are being worked out and special crews of men have been selected and trained to locate and repair any failures that may occur. Regular routine inspection is being made of the feeding reservoirs and of all manholes and the quantity of oil in the feeding reservoirs and water conditions noted and recorded and any unusual conditions reported at once.

The lines are provided with the usual automatic switches to open in case of failure and additional devices will be provided to indicate oil leaks as the life of the cable is brief, if it is not entirely filled with oil.

Repairs

Experience has shown that a leaky wipe on a joint in a manhole can be repaired in about 2 hr. by draining the oil out of the joint so as to remove the internal pressure. A stop-joint was replaced in about 15 hr. and a section of cable in 2½ days. It is thought that a failure in a joint which does not involve replacement of cable can be made in approximately 36 to 48 hrs. If the trouble or the replacement of the length of cable involves the entrance of a large amount of air into the cable, then it may be necessary to repeat the original process of evacuation and impregnation, requiring considerably greater time.

The time for all of these operations, however, will vary, depending on the location of the trouble and the profile of the section.

Conclusion. From the foregoing details it may be seen that many vital features employed in the manufacture, installation and impregnation of this type of cable will also impart a new direction to the attainment of better and more reliable cables of the ordinary type. The indications are that this cable marks a new epoch in cable engineering.

A Two-Range Vacuum Tube Voltmeter

BY C. M. JANSKY, Jr.*
Associate, A. I. E. E.
and
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Enrolled Student, A. I. E. E.

***Synopsis.**—The design, uses, and limitations of a new circuit employing the three-element vacuum tube as a voltmeter are discussed. Two overlapping ranges of voltage, together with a single operating battery, are the unique features. The effect of wave-form and the elimination of that effect are treated.*

* * * * *

THE need for a convenient means of measuring small alternating voltages has long been felt in the communication engineering field. The usual type of electromagnetic voltmeter is inadequate for two reasons: (1) Comparatively large current is required to operate it, and (2) its calibration is greatly affected by frequency. Both of these defects are more or less inherent and can probably never be materially reduced. The electrostatic voltmeter, while possessing neither of these defects, has others. Its sensitivity is exceedingly low, requiring the use of an optical system for voltages less than about 25 volts, and its adjustment is very difficult.

The versatile vacuum tube, however, possesses certain characteristics which make it applicable to the measurement of alternating voltages.

Various types of vacuum tube voltmeters are possible. One type uses a variable grid bias voltage which is made to balance out the plate current resulting when an alternating voltage is applied to the grid. This type measures peak voltages. Other types rely upon detector action of the tube. The voltmeter circuit described in this paper uses the grid bias method of detection; this is sometimes also called plate circuit detection.

Fig. 1 shows in schematic form the circuit which will be discussed. In order to obtain a wider range of voltage and still prevent grid current from flowing, two sets of plate and grid bias voltages are provided for. To obtain a means of rigidly fixing both of these voltages, they are taken as resistance drops in the filament circuit. The use of a UX-199 tube, requiring but 60 milliamperes for the filament, makes it possible to supply all power to the circuit from 45-volt, "B" batteries. Best results are obtained when two large-sized, 45-volt units are used in parallel. One set of resistances is used for the low-voltage range, the other for the higher range. When the higher range is in use, the grid is biased beyond the point where plate current normally disappears. For a fixed battery voltage, there exists an optimum proportion of voltages to give both the best, greatest sensitivity and the maximum range.

Since the resistance in the plate circuit is low (of the order of several hundred ohms), the plate current may be considered as vanishing at a bias voltage equal to the plate voltage divided by μ.

Let

E = available battery voltage,

E_b = supplied plate voltage (high range) which equals the voltage between plate and filament for high range,

e_b = supplied plate voltage (low range) which equals the voltage between plate and filament for low range,

E_c = absolute value of grid bias voltage used with high range,

e_c = absolute value of grid bias voltage for low range, optimum value,

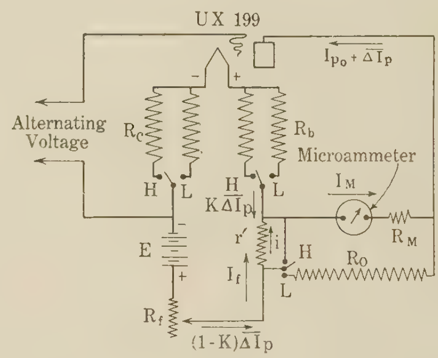

FIG. 1—SCHEMATIC DIAGRAM OF VACUUM TUBE VOLTMETER

V = maximum peak voltage which can be measured on high range without grid current flowing, ($V = E_c$)

v = maximum peak voltage which can be measured on low range without grid current flowing,

a = voltage which when added to e_c would reduce the plate current to zero; see Fig. 2.

Then,

$$e_c = \frac{e_b}{\mu} - a \text{ (a is positive)} \tag{1}$$

For the high range,

$$E_c - \frac{E_b}{\mu} \leqq v \tag{2}$$

in order to provide continuity between the two ranges. Also, for the high range,

$$E_b = E - E_c \tag{3}$$

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Putting $E_c = V$ into (3) and combining with (2),

$$V - \frac{E - V}{\mu} \leqq v \qquad (4)$$

For the low range,

$$e_b = E - b - e_c \qquad (5)$$

where b is the auxiliary balancing voltage used in the low range to balance out the normal plate current, I_{p_o}, and which was available in the high range for plate and bias voltage. Putting $e_c = v$ into (5) and combining with (1),

$$v = \frac{E - b - v}{\mu} - a \qquad (6)$$

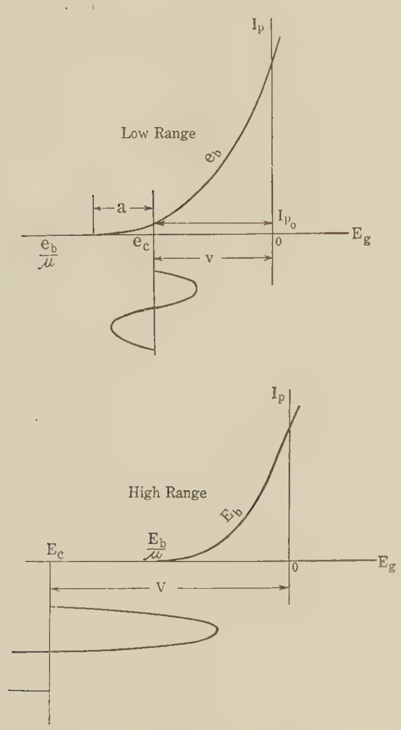

Fig. 2—The Double-Range Design

e_b = plate battery voltage
= plate filament voltage
e_c = operating bias
μ = voltage amplification factor of tube

Eliminating v between (6) and (4) gives

$$V \leqq (E - b - \mu a) \frac{\mu}{(\mu + 1)^2} + \frac{E - V}{\mu + 1} \qquad (7)$$

This equation expresses the maximum peak voltage measurable in a continuous two-range design, in terms of available battery voltage, voltage amplification factor and two design constants, a and b.

The constant a is determined by trial and was found to be of the order of one volt for several 199 tubes. Its value is not critical. The constant b is quite arbitrary, if R_o is adjustable for different tubes having different values of I_{p_o}, being equal to $I_{p_o} R_o$. For R_o = 50,000 ohms, b proved to be about three volts for one tube and five volts for another, using a 45-volt "B" battery as the source of voltage.

Using the guid ng equations derived above, the voltages, E_c, E_b, e_c, e_b, were selected and the resistances shown in Fig. 1 were obtained on the basis of 60-microampere filament current. Thus, E_c is determined by Equation (7), E_b by (3), e_c and e_b by (4) and (5), respectively. These values are not critical. A filament rheostat of 30 ohms was used so the maximum drop would be greater than 1.5 volts, permitting the

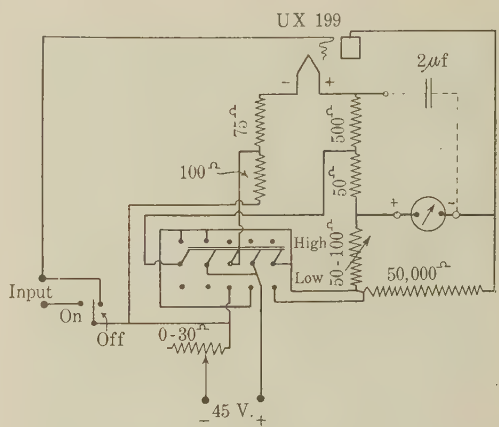

Fig. 3—Wiring Diagram of Assembled Voltmeter

e_c = 4.5 volts
e_b = 33 volts
E_c = 10.5 volts
E_b = 30 volts

use of dry cells to compensate for drop in B-battery voltage. The resistance r' was variable but could be rigidly set for a particular tube. It was found necessary to use a variable 100-ohm rheostat to accommodate the three tubes tested. There s a considerable difference between the normal plate currents for different tubes.

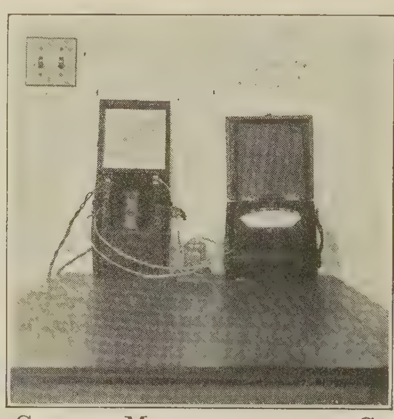

Fig. 4—Cabinet, Microammeter and Condenser

In fact, in the tube used in obtaining the data for this paper, a current of nearly two microamperes flows at the high bias, whereas in the other tubes tested, the plate current had entirely vanished at that bias.

The final arrangement is shown schematically in Fig. 3. A telephone key is used to change from one range to the other. A key is also provided to disconnect the voltmeter from the alternating voltage. This key

short-circuits the voltage terminals when the voltage is disconnected, in order to prevent the rise in plate current accompanying the free grid. The entire assembly of tube resistances and keys is mounted in a wooden case as shown in Fig. 4. Terminals are provided for the battery and the microammeter. In the tests herein described, a Rawson-type 501 microammeter having three ranges, 0-20, 0-200, 0-2000 microamperes, was used. An expensive calibrated instrument is not necessary, however; any D'Arsonval galvanometer movement provided with a scale and giving a readable deflection on a few microamperes will prove satisfactory. A more sensitive meter is not desirable due to difficulty which will be experienced in maintaining the false zero. In fact, slight fluctuations in battery voltage as well as shocks applied to the tube are observable on the 0-20-microampere range. The resistances are of the porcelain, tube-wound type and are not especially non-inductive. In the experimental work a condenser was sometimes used across the plate-filament as is shown in dotted lines in Fig. 3. The tube is mounted in a shock-absorbing socket.

Referring to Fig. 1, the application of Kirchoff's Laws to the balancing circuit gives the following equation:

Let

$$I_{po} = I_p \text{ when } I_M = 0$$

$$I_f r' = I_{po} R_o \qquad (8)$$

When an alternating voltage is applied to the grid, a mean increase in plate current, $\overline{\Delta I_p}$, occurs. In flowing from the filament, this increase divides between the two filament terminals in the ratio K as shown in the figure.

Thus, when $I_p = I_{po} + \overline{\Delta I_p}$,

$$(I_{po} + [1 - K]\overline{\Delta I_p} - i) R_o - (I_f + i) r' - (K\overline{\Delta I_p} + i) R_M = 0 \qquad (9)$$

But

$$K\overline{\Delta I_p} + i = I_m \qquad (10)$$

Combining (8), (9) and (10),

$$I_M = \overline{\Delta I_p} \frac{R_o + K r'}{R_o + R_M + r'} \qquad (11)$$

Equation (11) shows that the calibration is not independent of meter resistance. The lowest range of the Rawson microammeter has a resistance of about 1000 ohms which is not negligible compared with R_o = 50,000 ohms. The variation between the resistance of meters of various manufacture but of similar range, however, is not sufficient to cause more than 1 per cent error. Equation (11) gives the relative meter current in terms of the actual $\overline{\Delta I_p}$, K, and the resistances R_o, r' and R_M. It is to be recognized that changes in R_M as well as changes in filament rheostat (as made to compensate for falling battery voltage) theoretically change the actual mean increase by virtue of changing the plate circuit resistance. The value of K is also affected. No attempt has been made to obtain a mathematical statement of this; the effect is imperceptible. A further effect of varying the filament rheostat is to cause a slight change in the voltage applied to the circuit through the $\overline{\Delta I_p} \cdot R_f$ drop. This drop for the 30-ohm rheostat is negligible, also, being less than about 0.01 volt.

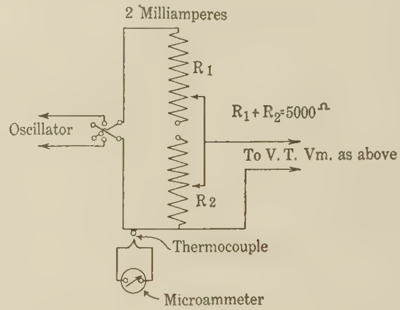

Fig. 5—Calibration Circuit

The following factors determine the usefulness of a tube voltmeter in communication measurements:

1. Variation of calibration with frequency,
2. Input impedance,
3. Variation of calibration with wave-form,
4. Sensitivity,
5. Range,
6. Stability of calibration.

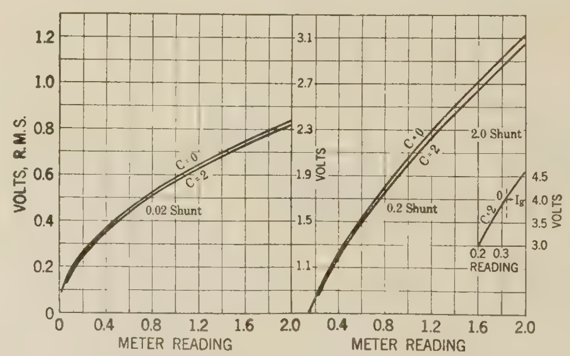

Fig. 6—Sample Calibration Vacuum Tube Voltmeter

Low range 1000 cycles
Low range zero = 0 on 0.02 shunt

Information concerning all of these factors has been obtained in the laboratory.

Fig. 5 shows the circuit used to calibrate the tube voltmeter. This circuit was also used for much of the test work. Calibration curves for the model studied in the laboratory are shown in Figs. 6 and 7. In addition to the fact that grid current reduces the input impedance, it biases the grid differently when flowing

through different resistances. Tests made using no grid bias verified this. The flow of grid current thus limits the range.

In order to interpret some of the subsequent results more intelligently, the effect of wave-form will be treated now. A consideration of the manner in which the mean increase in plate current arises shows that, in general, wave-shape does affect calibration. For almost all of the test work, the source of alternating current was a Western Electric 8-A oscillator comprising an oscillator, voltage amplifier, and power amplifier. Under load, the wave-form of the output current departs considerably from a sine-wave.

For the purpose of studying the effect of wave-form, oscillograms were taken of the current wave at different loadings. A precision-type radio-frequency milliammeter was used to maintain the current at a constant r. m. s. value of 20 microamperes for each load. The voltage drop to actuate the voltmeter was taken across a General Radio decade resistance box so that the voltage wave had substantially the same form as the current wave.

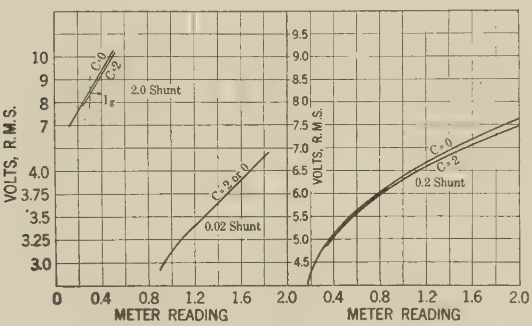

Fig. 7—Sample Calibration Vacuum Tube Voltmeter

High range 1000 cycles
High range zero = 0.14 on 0.02 shunt

Oscillogram (*a*) of Fig. 8 shows the wave-form with the oscillator loaded most heavily; (*b*) shows the wave-form under light load; and (*c*) shows the form improved slightly by means of a parallel "trap" circuit, tuned to 400 cycles, the frequency used. The following table gives the results:

TABLE I
FREQUENCY = 400 CYCLES PER SEC.

Volts r. m. s.	Reading	Zero scale	Reading	Scale	Cond. m. f.	Wave-form	Volts from curve	Per cent error
7.00	0.18	0.02	1.755	0.2	0	*a*	7.36	+4.90
*7.00	0.18	0.02	1.252	0.2	0	*a*	6.73	* −4.01
7.00	0.18	0.02	1.433	0.2	0	*b*	6.97	−0.42
*7.00	0.18	0.02	1.388	0.2	0	*b*	6.90	* −1.45
7.00	0.18	0.02	1.460	0.2	0	*c*	7.00	0
*7.00	0.18	0.02	1.403	0.2	0	*c*	6.93	* −1.01
7.00	0.18	0.02	1.890	0.2	2	*a*	7.40	+5.40
7.00	0.18	0.02	..	0.2	2	*b*	..	..
7.00	0.18	0.02	1.518	0.2	2	*c*	6.96	−0.57
0.70	0	0.02	1.345	0.02	0	*a*	0.701	+0.14
0.70	0	0.02	1.340	0.02	0	*b*	0.700	0
0.70	0	0.02	1.340	0.02	0	*c*	0.700	0

*Oscillator terminals reversed.

The per cent error in the above readings was referred to the reading with wave-form (*c*), designated by zero error for the reason that it coincided with the calibration. It can be seen that while none of the wave-forms photographed is so distorted as to be considered unsuitable for most work, errors in measurement may result if tube voltmeters are used, unless precautions are taken to eliminate them.

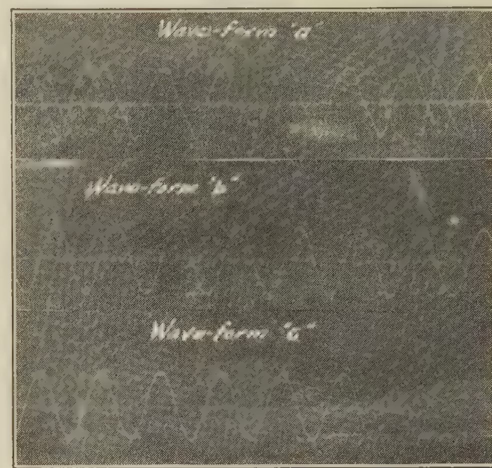

Fig. 8

The curves given in Fig. 9 show that the calibration does not vary appreciably with frequency. For each set of curves, a constant voltage across a non-inductive resistance was obtained by the aid of a precision thermal milliammeter. As would be expected, the use of a condenser connected between plate and filament prevents the slight falling off of the curves for higher frequencies due to the inductance in the plate circuit.

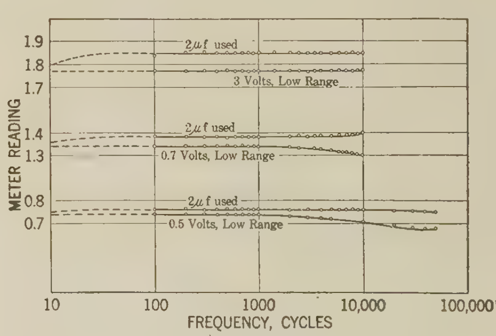

Fig. 9—Frequency Characteristic of Vacuum Tube Voltmeter

A two-microfarad condenser gave just as satisfactory results as one of larger value.

The input impedance of the tube voltmeter was measured with a shielded capacity bridge. The voltmeter was set up as for usual operation and the input impedance was obtained as a function of indicated plate current; see Fig. 10. The input capacity was found to be approximately 30 $\mu\mu$f. and the input conductance was found to be of the order of 0.004 micromhos.

The conductance increases rapidly as the grid approaches a positive potential. At 1000 cycles, the impedance is about five megohms.

The above measurements show that the input impedance of the vacuum tube voltmeter is entirely satisfactory for use in most communication engineering measurements. The device can not be used to measure voltage across a condenser unless a conductive path exists between condenser plates, inasmuch as the voltmeter has no grid leak of its own.

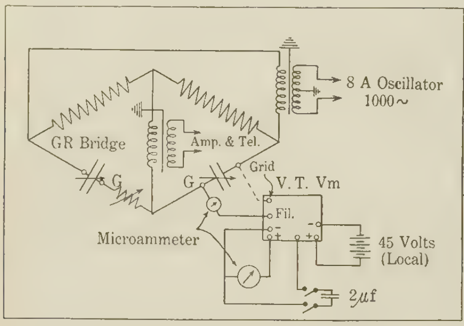

FIG. 10—SCHEMATIC DIAGRAM OF IMPEDANCE BRIDGE

Further notes on the method of calibration may be of interest. A frequency of 1000 cycles per sec. was used in the circuit shown in Fig. 5. The current was kept constant at two milliamperes and the load was kept fixed at 5000 ohms, non-inductive. The thermocouple, which was of the heater coil type, was calibrated with two milliamperes direct current immediately before use. The wave-form from the oscillator was satisfactory as the oscillator was not overloaded. Reversal of oscillator terminals had but little effect. Calibration curves were obtained both with and without two microfarads between the plate and filament. Condenser curves should be used for all frequencies about 100 cycles; below 100, the no-condenser curves should be used.

A re-calibration of the voltmeter described, made after about 40 hours of service, was found to coincide with the original calibration to within the limits of accuracy of the standardizing voltage. This is to be expected, as the method of adjusting for the false zero compensates for any change in emission. The change in filament current necessary to so compensate makes insignificant change in the operating voltages. As the tube nears the end of its life, however, its characteristics will change and compensation for the change in emission will not suffice, in general, to retain the calibration.

Aside from the use of the vacuum-tube voltmeter as a calibrated instrument to measure voltages, there is a wide field of use in which the device may be used as an intermediary in measuring a ratio of voltages. An illustration is the comparison of two impedances. In Fig. 11 is shown the scheme for comparing a scalar impedance with a resistance. The voltmeter is first connected across Z_x and the deflection noted, or the oscillator output is adjusted to give a conveniently readable deflection; it is then transferred to the voltage divider which is adjusted to give the same deflection. Care must be taken, if the wave-form is unsymmetrical with respect to the axis, to impress the same side of the wave toward the grid. In comparing an impedance of high phase-angle with a resistance, error arises even then if the wave-form is bad; for the harmonics in the current wave contribute to the voltage in different degrees in the reactance and resistance. This is exemplified by the fact that the measured impedance is different for reversed oscillator terminals, using the correct voltmeter connections as shown in Fig. 11. Measurements comparing the impedance of a 100-millihenry inductance with that of a resistance showed a discrepancy of the order of 5 per cent upon reversing oscillator terminals. When an inductance was connected in series with the resistance and the impedance of the resistance reduced to the same value as that of the inductance, thus making the phase angles in the two impedances equal, this discrepancy disappeared. Excellent sensitivity was obtained. The error of measurement was less than 0.5 per cent.

The tube voltmeter circuit under discussion cannot be used, without modification, except where the arithmetic mean of the voltage measured is zero. Measurements are frequently desired, however, of inductance or alternating voltage in iron core coils, transformers, etc., while carrying a polarizing or magnetizing current. One method of making such measurements is to employ the grid stopping condenser type of voltmeter. As pointed out by W. B. Medlam and U. A. Oschwald,* this type of voltmeter, however, has inherent objections such as enormous wave-form error, restricted range, and some frequency error. A preferable means of making the above measurements for transformers is to employ the plate detection voltmeter in a circuit shown in Fig. 12

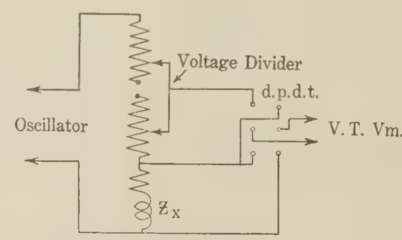

FIG. 11—COMPARISON OF IMPEDANCES USING VACUUM TUBE VOLTMETER

which was suggested to the authors by Mr. J. P. Barton, late of this laboratory, now of the Westinghouse Electric & Mfg. Co. By making r sufficiently low, of the order of a few hundred ohms, the current taken by the transformer can be reduced to a negligible amount; or, if not, corrections can be readily applied. Very satisfactory results have been obtained with this circuit in measuring voltage ratios of transformers, the manipulation being similar to the comparison of im-

*Bibliography, 1.

pedances. Here, the wave-form error cannot well be eliminated by a choice of voltmeter connections, and the best solution is to employ a good wave-form which, of course, is desirable from all standpoints.

Elimination of Wave-Form Error

Writing I_p as a function of E_g alone, as can be done when the plate circuit impedance is very low and E_p remains substantially constant,

$$I_p = f\,(E_g)$$

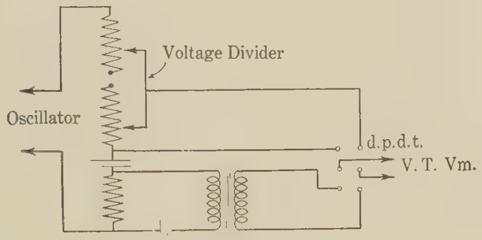

Fig. 12—Circuit for Measuring Transformer Characteristics

Let the steady current and voltage be I_{po} and E_{go}, respectively, and express the superposition of a variation in E_g as

$$I_{po} + \Delta I_p = f\,(E_{go} + \Delta E_g)$$

Expanding this by Taylor's theorem,

$$\Delta I_p = \Delta E_g \cdot \frac{d\ I_p}{d\ E_g} + \frac{\Delta E_g^2}{2} \cdot \frac{d^2\, I_p}{d\, E_g^2} + \frac{\Delta E_g^3}{6} \cdot \frac{d^3\, I_p}{d\, E_g^3} + \ldots$$

In general, this series would not greatly facilitate the study of the effect of wave-form where the variations E_g and I_p are wide, inasmuch as then the derivatives would vary over the range. In particular, however, if $I_p = A\,(K + E_g)^2$, the second derivative is constant $(= 2\,A)$ and all higher order derivatives vanish. Under this condition,

$$\Delta I_p = \Delta E_g \cdot \frac{d\ I_p}{d\ E_g} + \frac{\Delta E_g^2}{2}\ \frac{d^2\, I_p}{d\, E_g^2} \ \ldots \qquad (1)$$

It now becomes possible to compare ΔI_p for two unlike wave-forms A and B,

Let

$$\Delta E_{g_A} = {}^{M}E_A \sin \omega t \ \ldots \qquad (2)$$

and et

$$\Delta E_{g_B} = {}^{M}E_{B_1} \sin \omega t + {}^{M}E_{B_2} \sin (2\,\omega t + \alpha_2) + {}^{M}E_{B_3} \sin (3\,\omega t + \alpha_3) + \ldots + {}^{M}E_{B_n} \sin (n\,\omega t + \alpha_n) \qquad (3)$$

Further, let

$${}^{M}E_A = \sqrt{{}^{M}E_{B_1} + {}^{M}E_{B_2} + \ldots + {}^{M}E_{B_n}} \qquad (4)$$

to express equal r. m. s. values. Substituting (2) in (1) and integrating over a fundamental cycle to obtain the average change in plate current, ΔI_p,

$$\overline{\Delta I_{p_A}} = \frac{1}{2} \cdot \frac{d^2\, I_p}{d\, E_g^2} \cdot \frac{1}{2\pi} \int_0^{2\pi} [{}^{M}E_A \sin \omega t]^2\, d\,(\omega t)$$

as the periodicity of the first term causes it to vanish. Performing the integration,

$$\overline{\Delta I_{p_A}} = \frac{d^2\, I_p}{d\, E_g^2} \left[\frac{{}^{M}E_A^2}{4} \right] \qquad (5)$$

Now, substituting (3) in (1), gives for the mean change,

$$\overline{\Delta I_{p_B}} = \frac{d^2\, I_p}{d\ E_g} \cdot \frac{1}{4\,\pi} \int_0^{2\pi} \Bigg[\sum_{K=1}^{n} {}^{M}E_{B_K}^2 \sin^2 (K\ \omega t + \alpha_K) + \sum_{\substack{r=1 \\ r \neq s}}^{n} \sum_{s=1}^{n} {}^{M}E_{B_r}\, {}^{M}E_{B_s} \sin (r\ \omega t + \alpha_r) \sin (s\ \omega t + \alpha_s) \Bigg]\, d\,(\omega\, t)$$

The integrated value of the first summation can be shown to be

$$\pi \left[{}^{M}E_{B_1}^2 + {}^{M}E_{B_2}^2 + \ldots + {}^{M}E_{B_n}^2 \right]$$

while the integrated value of the double summation is zero over the cycle. The mean change in plate current then becomes

$$\overline{\Delta I_{p_B}} = \frac{d^2\, I_p}{d\, E_g^2} \left[{}^{M}E_{B_1}^2 + {}^{M}E_{B_2}^2 + \ldots + {}^{M}E_{B_n}^2 \right]$$

By (4) we have

$$\overline{\Delta I_{p_B}} = \overline{\Delta I_{p_A}}$$

which shows that for the quadratic characteristic the wave-form error vanishes. In special cases, the dis-

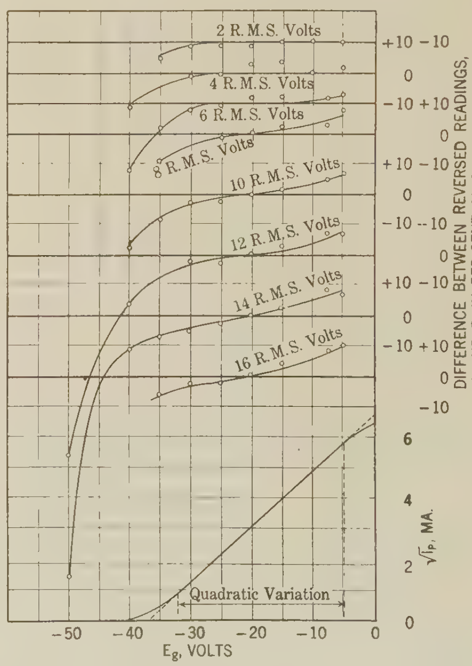

Fig. 13—Variation of Wave-Form Error with Bias

crepancy between two unlike wave-forms may vanish for a non-quadratic function, but this will not be so in general, as a consideration of the graphical treatment clearly shows.

The significant thing about the above demonstration is that the vacuum tube voltmeter may be freed from its greatest limitation by confining the range of variation of grid voltage to a substantially quadratic portion of the curve. No previous ireatment of this fact by others has been found by the authors.

Certain types of tubes display characteristics well suited for use in eliminating wave-form error. The low-μ power tubes, in general, have a relatively wide range of grid voltage over which the characteristic is quadratic. Fig. 13 shows the plot of the square root of plate current as a function of E_g for a UX-171 tube, and shows a range of about 27 volts over which the straight line indicates a constant second derivative. That the wave-form error is negligible over this region is shown by the other experimental curves of Fig. 13. They show the percentage difference between reversed readings for the unsymmetrical wave-form (a), previously referred to. The percentage is taken with respect to the readings reversed the same way throughout. These curves show that if the tube is operated at a bias voltage near the center of the quadratic region, a voltage considerably in excess of the quadratic limitation may be applied without wave-form error. Thus the 16-volt r. m. s. curve shows no error when operated at -20 volts bias although the peak of the wave is approximately 23 volts and exceeds the limit of quadratic variation by eight volts.

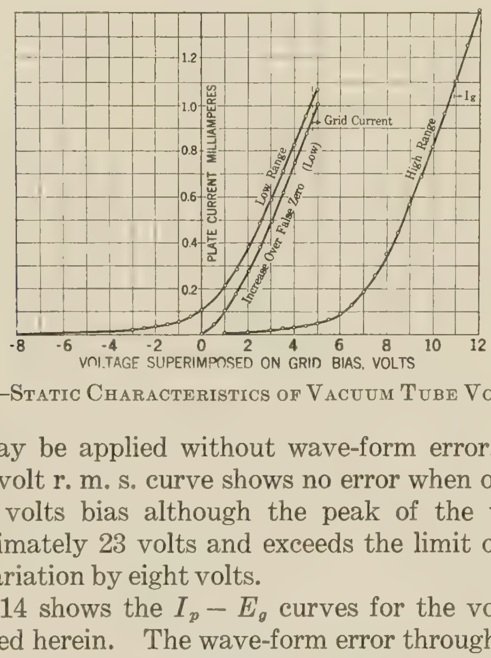

Fig. 14—Static Characteristics of Vacuum Tube Voltmeter

Fig. 14 shows the $I_p - E_g$ curves for the voltmeter described herein. The wave-form error throughout the low-range was found to be negligible for any of the wave-forms studied, despite the fact that the departure from quadratic variation is quite marked. It is only when the normal bias voltage is considerably in excess of that for which the plate current vanishes, that *slight* differences in wave-form are manifested by different readings in plate current. The plate current then depends solely on that portion of the voltage wave which projects beyond the vanishing point, and any hump or tip on the wave which might be insignificant compared to the entire wave is strongly instrumental in affecting the plate current.

Too much emphasis should not be placed on the elimination of wave-form error. The mere fact that a voltmeter reads r. m. s. volts independently of wave-form does not, of course, permit the indiscriminate use of any wave-form. In fact, in some instances, it might be desirable to use a voltmeter which would, by reversing terminals, detect an unsymmetrical wave-form.

Although the two-range voltmeter described herein is not capable of wave-form error elimination, its usefulness is not necessarily impaired. It does, however, on the higher range tend to *exaggerate* differences in wave-form. In passing, it may be said that this exaggeration is greater, according to the authors' beliefs, in the grid stopping condenser type of voltmeter than in the plate detection type. In fact, the former partakes largely of the characteristics of a *peak* voltmeter.

Of the six features of the vacuum tube voltmeter which were set down at the outset, the following may be said in summary concerning the two-range type studied by the authors:

1. Frequency has but little effect on the operation and this effect can be eliminated by the use of the by-passing condenser,

2. The input impedance is high, of the order of several megohms, and the power factor is low,

3. Differences in wave-form are exaggerated but not, for commercial wave-forms, objectionably so,

4. The senstivity is higher, perhaps, than that of most other communication-frequency measuring instruments. On the instrument designed by the authors, changes of 0.01 volt on the low end of the range, and changes of 0.05 volt on the high end are readily detectable,

5. The range is inherently low, covering, probably, a band of voltages from a tenth or a few tenths of a volt to about 10 volts,

6. The stability of calibration over the entire life of the tube is questionable. Experiment showed, however, that in general the calibration could be expected to remain constant for periods of operation of over 40 hr.

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In 1927 United States consumers purchased a half-billion of incandescent lamps which was some 24 million more than they purchased in 1926, the twelve-month period just past representing the largest in the history of the industry.

In ten years the sale of large lamps has doubled, and that of the miniature or small lamps tripled.

Illinois Central Suburban Service*

First Year of Electric Operation in Chicago

BY W. M. VANDERSLUIS[1]

Associate, A. I. E. E.

Synopsis.—*This paper gives operating records of the first year of electrical operation of the suburban service of the Illinois Central Railroad. It shows monthly curves of load, kw-hr. per car-mile, maximum demand, load factor and temperature. It also shows monthly curves for the last four years of passengers, car-miles, seat-miles and operating income. The improvements in service are enumerated and the general results at this date are discussed.*

* * * * *

Steam Operation

On July 21, 1856, the Illinois Central Railroad started suburban service in Chicago by running four trains each way between down-town Chicago and Hyde Park. It is recorded that the first train to Hyde Park did not carry a single paid passenger.

This service was gradually extended until, in July of 1926, there were in regular operation on each normal week day, a total of 398 trains with service extended to Matteon on the South, to South Chicago on the South Chicago Branch, and to Blue Island on the Blue Island Branch. In the year 1925, this steam service carried a total of 24,000,000 paid passengers. Approximately 285 coaches, mostly of wood construction and with an average seating capacity of 56 persons, were used in this service. About 60 locomotives were necessary for the daily operation.

Electric Operation

Electric operation for the suburban service has been agitated for years by various civic bodies, and the first formal report on feasibility and costs was made in November, 1909. This was followed by several other investigations and reports, but the railroad did not agree to the project until the passage of the so-called Lake Front Ordinance in 1919. This provided that the suburban service should be completely electrified by February 20, 1927. The commitment of the Illinois Central to electrify its tracks in the City of Chicago was a part of its general agreement with the City of Chicago, the South Park Commissioners and the War Department, covering riparian rights, changes in grades to permit of easy access to the lake front and changes in property ownership.

On July 21, 1926, exactly 70 years after the first steam service was started, three electric trains were operated each way in the local service between Randolph Street and Hyde Park. It will be noted that the electric service was started seven months before the time called for in the Lake Front Ordinance. The second week 80 trains were operated each day and in the period of about five weeks, the electric service was built up to a total of over 350 trains. These were all operated, of course, on the existing steam time-table, as there was still a considerable number of steam trains in the service.

The first electric time-table was put into effect on August 28th, with a total of 396 revenue trains. On account of a shortage of new equipment it was still necessary to run six trains by steam, but these were confined so far as possible to those carrying shop employes.

To-day, 470 revenue trains are being operated on a normal week day. In addition there are 14 equipment trains and 72 Chicago, South Shore and South Bend trains, the latter being operated between Kensington and Randolph Street. This is a total of 556 electric trains.

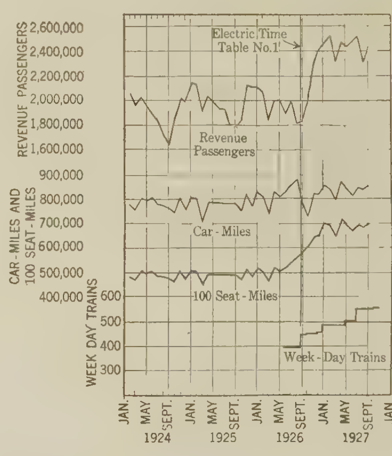

Fig. 1—Operating Curves Before and After Starting Electric Operation on Illinois Central Railroad

These curves show the number of revenue passengers per month, car-miles per month, hundreds of seat-miles per month and number of week-day trains per day

Electric service was put into effect without any serious accidents or interruptions and has so continued during the first year.

Due to the fact that all of the motor-trailer car units are uniform in design and in operating characteristics, the preparation of time-tables and the handling of equipment at terminal points has been greatly simplified.

Fig. 1 shows by months the revenue passengers

*For description of Illinois Central Suburban Electrification, see *Journal of Western Society of Engineers*, March, 1926, Vol. 31, No. 3. *General Electric Review*, April, 1927, Vol. 30, No. 4.

1. Electrical Engineer, Illinois Central Railroad, Chicago, Ill.

Presented at the Regional Meeting of District No. 5 of the A. I. E. E., Chicago, Ill., Nov. 28-30, 1927.

carried, car-miles and seat-miles operated and the week day trains in service.

Improvement in Service

Of particular interest is the improvement in running times due to electric operation. The latest electric time-table shows decrease in running times over the old steam service of from 11 to 28 per cent for the various classes of trains, the larger percentages resulting for trains to Kensington and beyond. The decrease in over-all time results from high maximum speeds and by the use of high accelerating and braking rates. Acceleration is at the rate of 1½ mi. per hr. per sec., which is about six times as rapid as that of through passenger steam trains. Under normal operation, a train will reach a speed of 28 mi. an hr. in 20 sec. After that point, the rate of acceleration falls off but on level tangent track a train will reach a speed of 50 mi. per. hr. in two minutes. With present average voltage conditions, balancing speed is about 64 mi. per hr. Although comparatively high braking rates have been accomplished on the steam trains, these also have been increased so that electric trains brake at the rate of 1¾ mi. per hr. per sec. It is significant that large decreases have been made in running times even on runs where more stops are made than formerly.

There has been a large gain in electric operation as compared with steam operation from the stand-point of operating a congested terminal. This improvement will become of greater importance as the service grows, inasmuch as under steam operation the limit to the number of trains physically possible to move in or out of the Randolph Street Terminal was rapidly being approached. It is readily apparent that this gain is made by the elimination of movements necessary for steam engines in changing ends of trains, and also in being brought from and taken to the engine terminal, since these movements must be made over the tracks serving useful train movements. The electric train requires only the normal loaded movements over these busy sections, except when brought from or taken to storage tracks at the beginning or end of rush hours.

The speed and reliability of electric service has been further enhanced by other improvements of the entire terminal. These include changes in the grades, rearrangement of tracks, elimination of railroad grade crossings, installation of high platforms at all suburban stations, installment of additional interlocking plants and rebuilding of the entire automatic block system to conform to electric traction requirements, a great part of which had been completed at the time of beginning electric operation.

Equipment

The results obtained from the motor-trailer combination have been satisfactory to the operating officers. The elimination of all steps on the cars for regular operation which requires high platforms, the use of sliding doors, fully enclosed vestibules, tight lock couplers, automatic acceleration and electropneumatic braking have all tended to increased convenience of the passengers and to safety and speed of operation.

The employment of a large amount of aluminum or aluminum alloys in side and roof sheets, doors, conduit and fittings has materially reduced the weight of the cars and, thereby, the operating expense.

For the year ending September 1, 1927, the average cost for maintaining the cars has been about six cents per car-mile. The weight of the motor car is 70.65 tons and the trailer 44.27 tons,—an average weight per car of 57.46 tons.

Delays due to electrical equipment have been very few and no radical changes in design have been found necessary. Minor changes incident to new designs have been made, but at very slight expense.

Fig. 2 shows the kw-hr. per car mile with corresponding average temperatures. Electric heating of cars is, of course, largely responsible for the variation between the different months, but changes in time-table also affect it slightly.

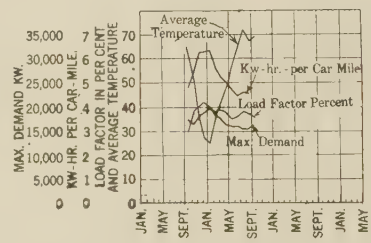

Fig. 2—Curves Showing Monthly Operating Records With Electric Service (Temp. in deg. Fahr.)

These curves show monthly averages of temperature and kw-hr. per car-mile, monthly load factor and monthly maximum demand.

Power Supply

For the year ending September 1, 1927 the total energy supplied under the contract with the Commonwealth Edison Company was 57,274,512 kw-hr. Of this, 92.7 per cent was for traction purposes including heating of cars, 6.1 per cent for light and power, and 1.2 per cent for signals.

Fig. 2 also shows the maximum demands by months and the variation with the temperature.

The contract provided that the railroad company guarantee a 30 per cent load factor. Fig. 2 shows the variation in the load factor. It will be noted that it is well above the guarantee.

Fig. 3 shows typical summer and winter week day load curves.

The supply of energy by the power company in specified feeders to the right-of-way line of the railroad company from the seven substations has been looked upon from some quarters with misgivings. This requires that not only the conversion machinery but all protective apparatus in the railroad company's feeders be maintained by the power company. The railroad company, however, has taken over, under normal

operation, the control of all traction feeders by use of its supervisory control system.

So far the results obtained have been satisfactory with the power company's broad-minded policy in operating under the necessarily somewhat complicated agreement.

Discrimination of the high-speed circuit breakers has been excellent. The overhead network on a multiple track railroad such as this installation covers is complex due to a necessity, in case of a fault, of having a minimum amount of track out of service. Isolation of individual sections in case of trouble has come up to expectations with very good protection to line and equipment. Furthermore, the power supervisor controlling the traction feeders has immediate information as to opening of breakers. He is located in the office of the train dispatcher, so that by working close together, trouble from a train going from a live to a grounded dead section has been minimized. The use of wayside signals indicating a dead trolley section at points where the sectioning is outside the limits of interlocking plants has also saved burn-outs of overhead.

The cold weather of the first winter indicated that a few minor changes, especially in pull-offs, were desirable. The delays which have occurred, however, have been small considering the size of the installation and the number of trains operated.

General Results

As indicated on Fig. 1, it is apparent that the traveling public will use a clean, fast and reliable transportation system. The off-peak business has increased

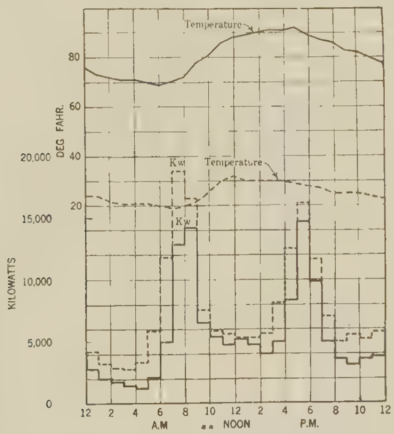

Fig. 3—Typical Summer and Winter Week-Day Load Curves and Temperatures

Full lines are for typical summer day, July 27, 1927 (time table No. 5). Dotted lines are for typical winter week-day curve, January 25, 1927 (time table No. 4)

materially, which, of course, is the most satisfactory business to have.

As announced in the newspapers recently, the operating income is now on the right side with an indicated profit of about $530,000 for the year 1927 as against a loss for the year 1926 although the electric service was in operation four complete months during that year. It is pointed out, however, that these figures do not take into account any investment in road and equipment. In providing the electrified service the railroad spent ten and one-half millions of dollars for new equipment, about four

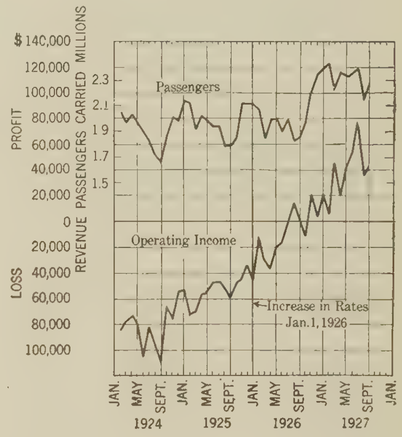

Fig. 4—Curves Showing, Monthly Net Operating Income and Number of Passengers Carried per Month

Figures for Illinois Central suburban service including Chicago, South Shore and South Bend Railroads

millions for electrical work, including overhead, switching equipment, return system and miscellaneous, and about nine and a half millions for rearrangement of old tracks, new track and station facilities and separation of grades, or a total of twenty-four millions in improvements only. An additional twenty millions of dollars was spent in the rearrangement of the terminal facilities for the whole electrification project.

Fig. 4 shows the relation between operating income and passengers carried for the three and one-half years.

TRANSLUCENT BLACKBOARDS

In connection with the annual meeting of the American Physical Society, held during the past summer in Reno, Nevada, a paper covering the latest development in blackboard illumination was presented by W. H. Weniger and H. R. Vinyard of the Oregon Agricultural College. The following extract of the paper appears in the *Physical Review* for September:

"The solution of a difficult problem in blackboard illumination was obtained by abandoning the usual opaque board and substituting therefor a ground glass surface uniformly illuminated from the rear. With customary room illumination, part daylight and part electric, everything on this "blackboard" was visible from all parts of the room, even from points making an angle of only 10 deg. with the plane of the writing surface. Incidental advantages gained are: ease of erasure; ability to use the surface as a translucent screen for projecting lantern slides with the possibility of adding chalk lines to projected diagrams; ability to intersperse chalk talks with lantern slides without changing the general room illumination."

Synchronous Motors for Driving Steel Rolling Mills

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and

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Synopsis.—It is the purpose of this paper briefly to discuss, from a practical standpoint, the application and design of synchronous motors for steel-mill main-roll drives, in an effort to show what their advantages and disadvantages are; where they should, and where they should not, be used; and what special precautions must be taken in the design of motors for this service.

DRIVING main rolls of steel mills is universally recognized as very heavy duty. The loads are high, and are applied and relieved very suddenly. Consider the case of a motor driving a single stand, Fig. 1. Between passes it will run with only 5 per cent to 10 per cent load, due simply to mill friction. As the metal strikes the rolls the load jumps almost instantly to possibly 100 per cent or 150 per cent of normal, and is as suddenly reduced when the metal leaves. This happens several times a minute. If such a drive has been properly selected, several passes on each bloom or billet may require 150 per cent to 175 per cent normal load on the motor. The load is intermittent in character, so that the motor is selected with the idea of permitting some of the passes to come up to these limits, so long as the r. m. s. value of the load is within the normal rating of the motor. If the heavier passes are of not more than three or four seconds duration a flywheel may be utilized to reduce the peak loads on the motor and power system.

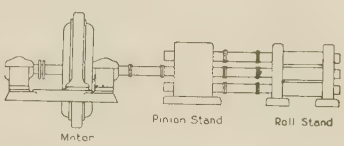

FIG. 1—ROLLING MILL, SINGLE STAND

With a mill having a train of several stands as in Fig. 2 or with a continuous mill as in Fig. 3, the drive is not subjected to quite as severe shocks as with a single stand, for it is apparent that as a piece of metal enters the mill the stands are filled in succession until all are full. The load increases to the maximum value in a number of steps, and is similarly reduced.

The torque required to start a mill from rest is often quite high in comparison to the capacity of the driving motor. This is especially true in cold weather, as very heavy grease is used on the roll necks and pinions, and this becomes very hard at low temperatures. Mills used for cold rolling thin sheets, which operate with very high pressure between the rolls and consequently on the bearings, may require as much as 200 per cent of normal motor torque to break them loose.

1. Both of General Electric Co., Schenectady, N. Y.

Presented at the Regional Meeting of District No. 5 of the A. I. E. E., Chicago, Ill., Nov. 28-30, 1927.

In addition to being able to start the mill, and carry heavy and sudden overloads, the drive must usually be capable of withstanding "plugging" in order to bring the mill quickly to a stop in case of a "cobble" or other mishap. Any piece of metal which fails to go through

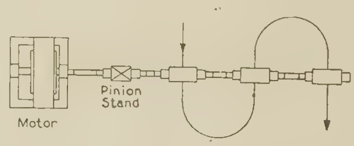

FIG. 2—ROLL TRAIN OF THREE STANDS

the mill properly is termed a "cobble." As soon as the operator sees that the steel is not going through as it should, he "plugs" the motor by disconnecting it from the line and then applying power with reversed phase rotation. After the mill stops, if the metal is not clear of all the stands, the portions between stands are cut out and then the motor must start the mill in the reverse direction to back out the pieces in the rolls.

Considering these conditions which a main roll drive must meet, it is not remarkable that for nearly all constant-speed electric drives induction motors of the wound-rotor type have been used. This type of motor has excellent starting characteristics, will carry heavy overloads, and withstands much abuse. In common with all induction motors, however, its power factor is lagging, and very much so in low-speed machines. Now, the main rolls and lay-shafts on heavy mills do not run at high speeds, and it is often desirable to direct-connect the motor, so that there are now in service many low-speed motors, operating at low power

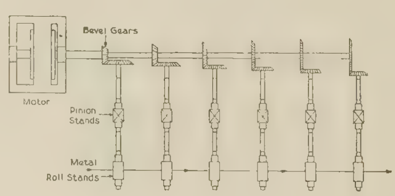

FIG. 3—CONTINUOUS MILL

factors. As a matter of fact, one reason for the use of 25-cycle power in numbers of steel plants is that low-speed 25-cycle motors have better power factor than the corresponding 60-cycle machines. The use of higher speed motors driving through reduction gears

has helped the situation somewhat, but has still left much to be desired in the way of power factor improvement.

Unquestionably the desire for a better operating power factor has been the chief factor in bringing the synchronous motor into consideration in steel mill service. It possesses, however, advantages other than

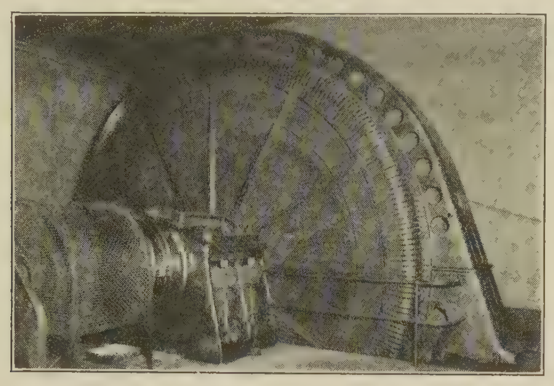

Fig. 4—9000-H.P., 107-Rev. per Min., 6600-Volt Synchronous Motor Driving a Continuous Sheet Bar Mill

This motor has a greater continuous horsepower rating than any other motor in industrial service.

its good power factor, as well as some disadvantages, and these will be brought out in the following detailed comparison of the characteristics of the two types of machines.

Field of Application of Synchronous Motor

The field of application of the synchronous motor in main-roll service is limited to strictly constant-speed drives. This eliminates it from consideration on reversing mills,—mills requiring flywheels, and mills needing adjustable speed.

It is not as a rule advisable to attempt to apply it to any type of mill which may have to be started with metal in the rolls, such as a cold strip mill, nor to cold sheet mills, which have excessively high friction. Such mills may require at starting considerably more torque than is needed to carry their full load at full speed, and unless the motor is sufficiently small in comparison to the power system so that it can be started at full voltage, difficulty may be experienced in getting started and synchronized.

In connection with constant-speed continuous mills of the type shown in Fig. 3, looping mills as illustrated in Fig. 2, and in fact, almost any constant-speed hot metal mill, the synchronous motor deserves very careful consideration. Every individual case must be studied very thoroughly to make certain that no misapplications are made. Careful thought must be given not only to the full-load rating required, but also to the maximum torque that may be necessary to break the mill from rest under the most adverse conditions; to the maximum torque needed at pull-in; to the torque required to back out cobbles; to the maximum peak load that may be encountered; to the kv-a. demand that the power system can stand without disturbance, while starting the motor; and last, but not least, to the characteristics that can be obtained in the motor, to determine whether it can meet the requirements.

Starting Characteristics

Practically the only reason synchronous motors have not been widely used on mill drives in the past is because their starting characteristics are not so desirable as those of the wound-rotor induction motor. For 100 per cent kv-a. input the induction motor develops approximately 100 per cent rated torque at starting, whereas the synchronous motor will give from 30 per cent to 60 per cent starting torque with the same kv-a. input at a much lower power factor. However, the torque obtainable from a synchronous motor is ample to start most types of mills, and its other advantages make it the logical choice in many cases.

By proper design, good starting torque characteristics, as shown in Figs. 5 and 6 can be obtained in mill type synchronous motors with a single squirrel-cage winding. The double squirrel-cage has, at times, been considered, but in each case it has been found that by the proper choice and distribution of materials in the bars and rings, the proper spacing of the bars with respect to the stator slot pitch and the depth and width of the slots in the pole face over the bars, the torque

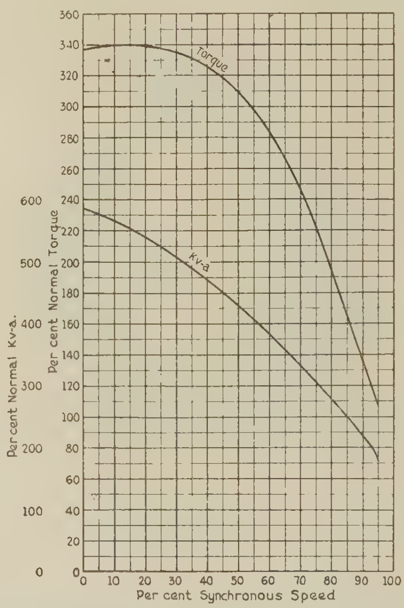

Fig. 5—Starting Characteristics of 6500-H. P., 0.8-Power Factor, 187-Rev. per Min., 6600-Volt, 25-Cycle Synchronous Motor, from Test Data

requirements have been amply met with a single squirrel-cage. In practically all cases it has been found possible to obtain more than sufficient torque to start and bring the mill to synchronous speed, or to even back out a cobble, with from 70 per cent to 100 per cent normal kv-a. input. Unlike that of the squirrel-cage induction motor the squirrel-cage of the synchronous motor can

be changed in design at will, with a corresponding change in torque characteristics, without affecting the efficiency of the synchronous motor during its normal operation under load.

The curves shown give the torque and kv-a. values with full voltage applied to the motor. In normal operation of course, these large motors are started at reduced voltage obtained from a suitable auto-transformer. For example, the 6500-h. p., 187-rev. per min. motor for which starting torque and kv-a. curves are

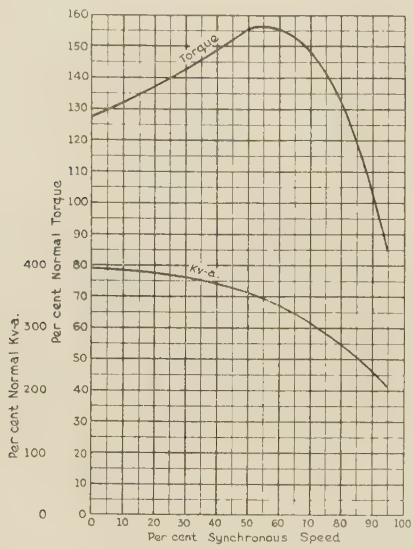

Fig. 6—Starting Characteristics of 5000-H.P., 0.85-Power Factor, 240-Rev. Per Min., 2200-Volt, 60-Cycle Synchronous Motor, from Test Data

shown is regularly started on 32 per cent voltage. Since the starting torque and kv-a. input varies as the square of the voltage, it is apparent that under this condition the motor demands only 60 per cent of normal kv-a. and gives about 35 per cent of its normal torque. This has proved ample to start the mill under all conditions. Similarly, a 9000-h. p., 107-rev. per min. motor is always started at 32 per cent voltage, giving 27 per cent of normal torque with 70 per cent normal kv-a.

The "pull-in" torque, or the torque available at approximately 95 per cent synchronous speed before the application of field, must of course be in excess of the mill friction at this speed, but can be considerably less than the starting torque, as the latter must overcome the "dead" friction of the mill, with the bearings practically dry.

The fields of these motors are usually wound for 250-volt excitation, and if the field were left open-circuited at starting the induced voltage across the rings, with 33 per cent normal voltage applied to the stator, would be from 5000 to 10,000 volts. In order to protect the operators from the induced field voltage it is the practise when starting, to close the field circuit through a discharge resistance. While this increases the starting current and decreases the starting torque to some degree, it also increases the pull-in torque. The amount and capacity of this resistance to give the best torque characteristics can be determined by calculation.

A synchronous motor may be plugged for a quick stop, by first opening the "forward" breaker and removing field, then closing the "reverse" breaker and connecting the motor to the starting tap of the auto-transformer. The current drawn when plugging is approximately 15 per cent more than the starting current, and the torque developed about 75 per cent of the torque at starting.

Maximum Torque

A synchronous motor can be designed for fully as high maximum or pull-out torque as an induction motor and for steel mill service this pull-out torque varies from 225 per cent to 300 per cent of normal full load running torque. The synchronous motor has the advantage that for any reduction in applied line voltage the pull-out torque decreases only in direct ratio to the voltage, whereas the torque of an induction motor decreases as the square of the voltage. Furthermore because of its better power factor, the synchronous motor helps to maintain the voltage at its terminals; consequently the drop in line voltage due to a given load is not likely to be so great as if an induction motor were used.

Power Factor

One of the most desirable features of the synchronous motor is its ability to improve the power factor of the system on which it operates. It is usually designed to give a leading power factor at normal load, and will then

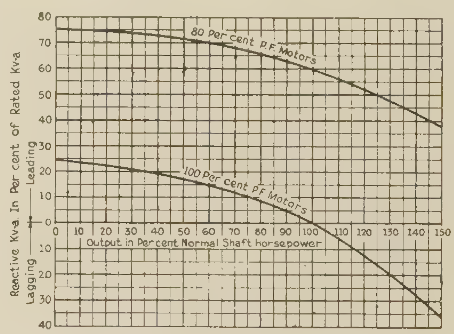

Fig. 7—Approximate Reactive Kv-a. Available for Power-Factor Correction, with Field Excitation Constant at Normal Load Value

furnish a considerable amount of corrective kv-a. at all loads up to a considerable overload, as shown in Fig. 7. The low power factor of low-speed induction motors, particularly 60-cycle machines, has necessitated the use of reduction gears in some cases where for other reasons a direct drive would have been preferable. The use of synchronous motors permits direct drive with low-speed machines, operating at unity or leading power factor.

Efficiency

Two curves are shown, illustrating the very high efficiency obtained from large synchronous motors, both 25 and 60 cycles. The fact that approximately 75 per cent efficiency is obtained at 5 per cent of normal load is quite noteworthy.

The full-load efficiency of synchronous motors for steel mill service varies from 0.5 per cent to 2 per cent more than that of the corresponding induction motors. This better efficiency of course means some saving in power cost.

Operating Voltage

Synchronous machines can very readily be built for any operating voltage up to and including 13,200. While a very few induction motors are operating at 13,200 volts, it is better practise not to exceed 6600 volts on an induction motor, as the design becomes difficult and the machine expensive.

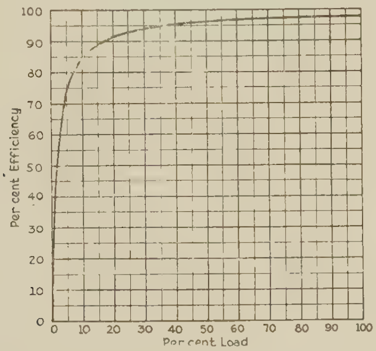

Fig. 8—Efficiency of 9000-H. P., 1.0-Power Factor, 107-Rev. Per Min., 6600-Volt, 25-Cycle Synchronous Motor, from Test Data

Excitation

One disadvantage of the synchronous machine is that it requires a separate source of excitation, while the induction motor does not. On an important drive it is wise to employ an individual exciter, either direct connected or driven by a separate motor. The excitation voltage is always 250, so that as an emergency source the 250-volt d-c. power circuit which exists in all steel mills can be used.

Floor Space

The amount of floor space required by a synchronous motor is almost invariably less than that needed for an induction motor of the same rating. One reason for this is that it is the usual practise to make the motor base long enough so that the stator can be moved along the shaft a sufficient distance to make both rotor and stator windings accessible for cleaning or repairs. The rotor of an induction motor is inherently somewhat longer than that of a synchronous motor, because of the space required for the end connections of the coils on the former, and this necessitates a greater space for movement of the stator.

The following table shows the relative base dimensions of the two types of motors, for several different ratings:

Rating			Floor Space: Synchronous Motor							Floor Space: Induction Motor						
H. P.	Rev. per min.	Cycles	Ft.	In.		Ft.	In.		Sq. ft.	Ft.	In.		Ft.	In.		Sq. ft.
9000	107	25	18	0	x	24	8	=	445	20	7	x	25	0	=	515
6500	187	25	17	5	x	15	7	=	272	16	7	x	19	3	=	319
5000	100	60	13	2	x	21	11	=	288	16	8	x	23	11	=	398
5000	240	60	13	8	x	14	2	=	195	14	0	x	16	0	=	224
5000	83	25	14	3	x	19	9	=	282	15	0	x	20	0	=	300
1500	300	25	10	10	x	11	8	=	123	12	3	x	11	9	=	143

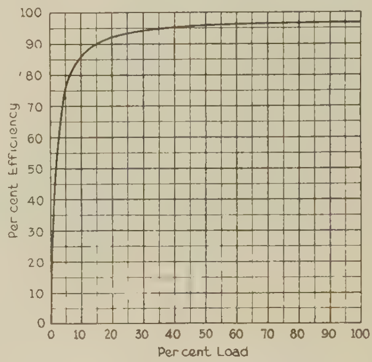

Fig. 9—Efficiency of 5000-H.P., 0.85-Power Factor, 240-Rev. Per Min., 2200-Volt, 60-Cycle Synchronous Motor from Test Data

Fig. 10—Stator Frame Fabricated from Steel Plates and Bars

Speed Control

Control, or rather adjustment, of the speed of a synchronous motor in mill service is of course impractical, and its use must, therefore, be confined strictly to constant-speed mills. This fact also eliminates it from consideration on any so-called constant-speed mill on which a flywheel is necessary, for to get any beneficial effect from the wheel the speed must vary inversely with the load.

The fact that the motor runs at truly constant speed, except for what variation in frequency occurs on the system, is an advantage on some types of mills. For example, if the product from a continuous mill of the

type shown in Fig. 3 is cut into lengths by a flying shear, as it leaves the mill, the lengths will be more uniform if the mill speed is absolutely constant than if it varies slightly.

Cost

The cost of a synchronous motor, of the capacity used for main roll drives, complete with exciter and control, is usually less than that of a similarly rated induction motor. For machines of medium capacities, speeds and voltages, the differential is not great, but for large low-speed units, the synchronous machine is considerably less expensive.

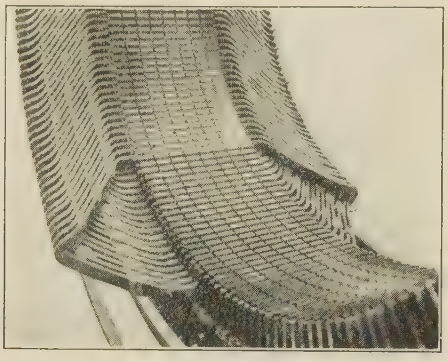

Fig. 11—Partly Wound Stator, Showing Method of Bracing the Coils

Reliability and Ease of Repair

From the standpoint of reliability it can hardly be said that either type of motor has the advantage. A machine any more reliable than the well built mill-type induction motor has proved itself to be, would be difficult to find, but there is no reason why the synchronous motor should not have an equally good record in the years to come.

As far as ease of repairing is concerned, the stators of the two machines are practically on a par. The coils of the synchronous motor are somewhat larger and heavier as a rule, but there are fewer of them. The rotor of a synchronous motor could probably be repaired more quickly than that of an induction machine. The fact that the synchronous motor has a fairly large air-gap helps to facilitate the moving over of the stator for cleaning or repairs.

Construction

Obviously the details of design and construction described in the following paragraphs apply to motors built by the company with which the writers are associated. The practise of other manufacturers may differ in some respects.

The mechanical and electrical construction of the mill-type synchronous motor is fully as sturdy and reliable as that of the mill-type induction motor. The quantity and kind of the materials used are such that all stresses are kept within a conservative minimum.

The stator frames of the earlier motors of this type are of cast iron. Those built within the past year and a half, however, are fabricated of steel plates securely welded together and braced to form an exceedingly strong and rigid structure. To the inner periphery of the frame are welded steel dovetailed keys. The core laminations are held on these keys and clamped between heavy welded steel finger flanges. Air ducts are provided in the core and complete ventilation is further accomplished by the use of air-slide wedges.

Because of the size and weight of the stator coils in these large motors they are insulated very carefully to protect them from mechanical injury. After their assembly in the stator the end projections are securely laced to insulated steel bracing rings which are supported from the stator frame. The larger machines are supplied with resistance temperature detectors. The stator coils are liberally designed to safely take care of sudden overloads or the condition where the motor may be required to develop its maximum torque as an induction motor.

The rotor spiders of the machines of small diameter are built up of laminations punched from heavy steel plates, those of larger diameter being of cast steel. The laminated pole pieces are either dovetailed into the punched rotor or secured to the cast rotor by means of bolts screwed into steel keys imbedded in the pole pieces.

The field windings are usually of edgewise-wound copper strip. Here again great care is given to the insulation between the turns of the winding, and of the coils as a whole from the pole pieces and rotor spider. One of the recent improvements in design consists in the addition of fins to the ends of the field coils which are made by simply projecting every second or third turn during winding. These fins provide an increased area of radiating surface on the ends of the coils and have proved very effective in reducing the field temperature.

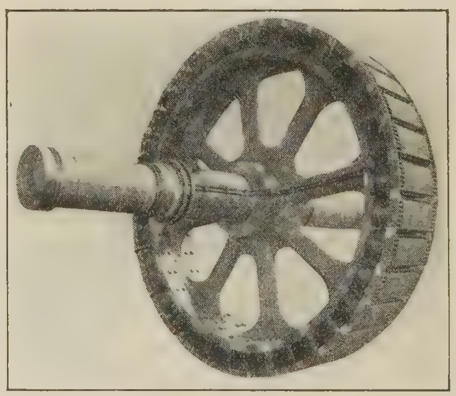

Fig. 12—Rotor with Cast Steel Spider

Since, at times, these motors may be required to develop their maximum torque as induction motors, considerable attention is given to the heat storage capacity of the amortisseur winding, the materials

used being such that their strength will be retained at high temperatures. The bars are silver soldered into the end ring segments. The end ring segments have bolted joints between poles so that each individual pole may be readily removed from the rotor without disturbing the others.

The specially designed mill-type pedestals are securely bolted to both the base and foundation. They are equipped with babbitted thrust collars when this feature is desired. These pedestals are insulated from

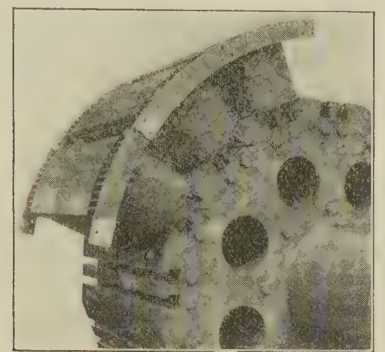

Fig. 13—Rotor with Laminated Spider

the base to eliminate the possibility of shaft currents. The spherical-seat, self-alineing bearings may be equipped with temperature relays. A liberally designed ring oiling system insures ample lubrication but in addition, provision is made so that flood lubrication may be applied.

The base is provided with rollers under the carrier plates supporting the stator feet in order that the stator frame may be easily moved in a direction parallel to the shaft. The carrier plates are keyed to the base in order to maintain the alinement of the stator frame during this movement.

Air heaters may be installed in the lower halves of the stator frames of these motors to prevent the possible accumulation of moisture on the windings in case the mill is idle for any considerable length of time.

Control

A few main-roll synchronous motors are started at full voltage, but most of them are so large that such practise is not desirable because of the resulting demand on the power system. Consequently, an auto-transformer is usually employed to give reduced voltage for starting. For some of the largest machines it has proved desirable to employ two reduced voltage steps in the starting operation, and to meet this condition the combination Korndorfer and reactor method illustrated diagramatically in Fig. 14 has been developed.

The sequence of operations for starting, stopping, or plugging the motor is initiated by the simple movement of the handle of a master switch placed near the mill, and the operation is completed automatically under the control of relays on the control panel.

We will assume that the motor is at rest and that the operator throws the handle of the master switch to the "forward" position. Oil circuit breaker *A* closes at once, establishing the neutral connection of the auto-transformer,—*F* follows immediately, connecting the line end of the auto-transformer to the line and thereby applying the first step of reduced voltage to the motor. With this voltage the motor should start and gradually increase its speed.

When it reaches a predetermined speed, usually from 50 per cent to 75 per cent of synchronism, as indicated by the frequency obtained from a small pilot generator on the main motor, a relay operated in response to the frequency causes breaker *A* to open, and immediately thereafter breaker *B* closes. *B* connects the motor to the line through the reactor. The reactor is so proportioned that the voltage drop across it at the time it is connected in the circuit is sufficient to reduce the voltage at the motor to a value between the line voltage and that given by the auto-transformer tap. As the motor speed increases, the current will drop and the voltage at the motor terminals will rise.

When the motor reaches approximately 95 per cent synchronous speed, as determined by a relay which operates only when the difference between the line frequency and the pilot generator frequency is 5 per cent or less, field excitation is applied, of sufficient value to give approximately unity power factor. This pulls the motor into step, and so reduces the current drawn by the motor through the reactor that the voltage at the motor terminals increases almost to the line value.

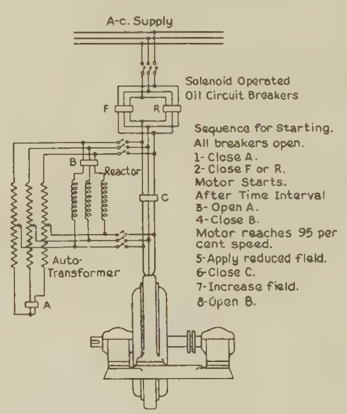

Fig. 14—Elementary Diagram of Combination Korndorfer and Reactor Method of Starting Synchronous Motors

After a short-time interval, breaker *C* closes, *B* opens, and the field excitation is automatically increased to the full value.

It will be noted that at no time during the sequence of starting operations is the motor entirely disconnected from the line. Furthermore, owing to the use of the reactor, the transition from the second starting voltage to the line is made with extreme smoothness.

Protection is provided against under-voltage, loss of

excitation, and failure to synchronize within a definite interval after the master switch is operated.

The control equipment for a synchronous motor involves more oil circuit breakers than does that for an induction motor, but the latter requires a number of large contactors and resistors for its rotor circuit, with relays for controlling the same. Neither is especially complicated in installation or maintenance. So far as the mill operator is concerned, he simply moves the handle on one kind of master switch to start either type of motor.

Installations

A considerable number of synchronous motors is now installed or being built for main roll service. Those supplied by one manufacturer include the following:

A 9000-hp., 107-rev. per min., 25-cycle, 6600-volt unit is driving a continuous sheet bar mill at the Cleveland plant of the Corrigan-McKinney Steel Company. This motor has a higher continuous horsepower rating than any other motor in industrial service in this country.

Two motors, one 6500-hp., 187-rev. per min. and the other 4000 hp., 83 rev. per min., 25 cycles, 6600 volts, form part of the drive of a continuous skelp mill at the Bethlehem Steel Company's Sparrows Point plant.

A 5000-hp., 240-rev. per min., 60-cycle, 2200-volt synchronous motor is being installed to drive a tube piercing mill at the Standard Seamless Tube Company's plant at Economy, Pa.

The Continental Steel Corporation, Kokomo, Indiana, has purchased a 5000-hp., 100-rev. per min., 60-cycle, 2200-volt motor to be used in driving a continuous sheet bar mill.

The Copperweld Steel Company of Glassport, Pa. will use three 60-cycle, 2300-volt synchronous motors, one 600-hp., 400-rev. per min., one 600-h. p., 514-rev. per min. and one 600-h. p., 900-rev. per min. to drive various merchant and rod mill stands.

Two 400-hp., 720-rev. per min., 60-cycle, 4600-volt motors have been purchased by the Higgins Brass and Manufacturing Company, Detroit, Michigan, to drive brass and copper mills.

Another manufacturer has built several synchronous motors for seamless tube mill service, some of them being for piercing mills and some for tube rolling mill drives.

Conclusion

The foregoing discussion, we believe, has made clear that the synchronous motor is a real competitor of the wound-rotor induction motor for some types of main roll service. The number of installations which have been made within a comparatively short space of time certainly proves this contention. The synchronous motor has certain definite advantages, such as better power factor, efficiencies, and cost, which make it very attractive. Its starting characteristics are not so good as those of the induction motor, but for many drives they are sufficient and on those mills it can often be used to advantage.

It seems safe to predict the widely increasing use of the synchronous motor in mill service, and with this prediction goes the hope that such motors will be applied, designed, and built only with a full knowledge of the demands of the load and the limitations of the motor.

RECENT PUBLICATIONS BY THE BUREAU OF STANDARDS

ABSOLUTE MEASUREMENT OF CAPACITANCE BY MAXWELL'S METHOD by Harvey L. Curtis and Charles Moon. Scientific Paper No. 564.

Abstract: The absolute measurement of capacitance by Maxwell's method is based on the assumption that certain conditions are fulfilled by the experimental apparatus. While there are at least seven of these conditions, the most important is that the galvanometer correctly integrates the current. When large capacitances are measured, a galvanometer is required in which the current through the coil does not affect the magnetism of the permanent magnet. By placing the coil in a symmetrical position with respect to the magnet this condition can be fulfilled in most galvanometers. However, this adjustment is greatly simplified by a proper design of the galvanometer.

The method requires that a condenser shall be charged and discharged at a known rate. To accomplish this, contacts of platinum dipping in mercury cups have been placed on the prongs of a tuning fork driven by an electron tube. This permits the Maxwell bridge to be balanced with the same ease and accuracy as a Wheatstone bridge. However, it is necessary to determine the frequency of the fork at the time of measurement. For this purpose the fork is compared with a freely vibrating pendulum by a method which gives an accuracy of a part in a million with observations which extend over a few minutes' time.

INDETERMINATENESS OF ELECTRICAL CHARGE by Chester Snow. Scientific Paper No. 566.

Abstract: It is shown that if every electric charge in the world be given a charge of true magnetism, their ratio being a constant, the change could not be detected. If the electric and magnetic charges of an electron are, respectively, ϵ_1 and λ_1, then we have measured only $\sqrt{\epsilon_1^2 + \lambda_1^2}$. The algebraic signs of ϵ_1 and λ_1 are arbitrary, but the ratio ϵ / λ must be the same as for a proton and is physically indeterminate. The proposition may be regarded as a one-parameter transformation of the electromagnetic field components (in the same system of coordinates), which leaves the electromagnetic energy tensor unchanged. This indeterminateness is rooted in the electromagnetic scheme and, therefore, pervades the interior of all electrons which have been constructed on that scheme.

Abridgment of

The Application of Relays for the Protection of Power System Interconnections

BY L. N. CRICHTON[1] and H. C. GRAVES, Jr.[1]

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Synopsis.—*This paper is a compilation of many of the new methods for relay protection required by superpower interconnections. The ideas have been obtained from various sources and represent good present day practise. The general requirements for such interconnections are mentioned with particular reference to protection against phase-to-phase short circuits in those cases where the short-circuit current, under certain system conditions, is less then the full-load current under other conditions. The clearing of accidental grounds is discussed and a new study of residual currents on systems of different types is given. This study indicates the usefulness of certain inverse time limit relays on systems having dead grounded power transformer neutrals at all switching stations. Bus protection and "back-up" methods are described.*

Some of the new relays which have been developed, or improvements which have been made to older types in order that the new demands may be met, are described; and there is illustrated a typical relay installation similar to that now being placed in service on a 220-kv. interconnection.

* * * * *

THE interconnection of large power systems requires special treatment of its protective relay installation in order to secure proper automatic sectionalizing. This is particularly true of extra high-voltage interconnections which have their transformer neutrals grounded at all stations. Such systems are not numerous, but they are important and their number is increasing. In any such relay installation it is important to adopt protective methods which not only are suitable for the immediate requirement but which will be applicable to future revisions and extensions. Interconnections between large power units impose more strenuous demands on the relay protective equipment than do individual systems, even those of a large size.

Relay Requirements

The most important requirement is that all faults be cleared quickly. This prevents unnecessary burning of conductors and equipment, but primarily, such quick clearance will minimize the possibility of the system becoming unstable. Therefore the securing of discrimination by means of time limit relays is not desirable although it may sometimes be necessary or convenient.

The complete installation must allow flexibility of system operation. Perfect protection should be possible when any line or piece of equipment is cut out of service and, what is more difficult, protection should be obtained without change in relay adjustment when a large unit of power is entirely removed.

The initial relay installation should permit unlimited extension and revision of the power system.

It should operate satisfactorily on the lines forming the interconnection between the systems without requiring too great a change in the relay protection already installed on the individual systems which are being united.

It must protect against "bus faults." High-voltage switching stations have become so elaborate that the possibility of trouble on the bus bars or on the station equipment is as great as that on a number of miles of transmission lines.

It must provide "back-up" protection, by which is meant that trouble should be cleared from the system, possibly with some little delay, even though the circuit breaker which would ordinarily clear such trouble should fail to operate. Some types of relays will operate in this manner by means of their inherent characteristics, but other types require the use of additional relays. For simplicity, so it is desirable that protection against bus faults and back-up protection be obtained by the same means, thus making unnecessary the use of complicated differential schemes commonly used for bus protection.

It is desirable to eliminate the use of high-voltage potential transformers so far as possible, not only because of their expense, but also because of the hazard which they, themselves, introduce in the system.

Economy in the relay system is desirable, but because high-voltage lines and equipment are inherently expensive, if such a procedure results in eliminating more expensive high-voltage equipment, the best over-all economy may be obtained by adopting an expensive relay system.

Types of Relays Considered. In order to satisfy the needs of recent interconnections, a number of new methods of using the conventional types of relays have been developed and entirely new relays have been designed; namely:

For protection against short circuits,

1. Low-current range impedance relay (type *C Z*).
2. Fault detecting over-current and undervoltage relays.

For protection against grounds,

1. Both of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Presented at the Regional Meeting of District No. 5 of the A. I. E. E., Chicago, Ill., Nov. 28-30, 1927. Complete copies upon request.

3. Definite time, directional relay with phase compensation in the potential circuit (type *C R*).
4. Definite time, current directional relay (type *C R C*).
5. Inverse time, current directional relay (type *C W C*).
6. Inverse time, directional relay with phase compensation in the potential circuit, (type *C W*).

The use of these new methods and devices will be described herein with only brief references to methods which are already in common use.

Protection Against Phase-to-Phase Faults

General Conditions. The nature of a high-voltage interconnection system is such as to make difficult any application of relay equipment which will satisfy the demands previously enumerated. The purpose of an interconnection is usually to permit the exchange of power, and any number of causes may necessitate periodic changes in location of connected generating capacity. These changes may occur daily due to load conditions, or seasonally due to change in available generator capacity. This results in a change in magnitude of fault current, due not only to the variation in total connected generating capacity but also to the change in location of this capacity. Thus, at some points on the system, it is quite conceivable that fault currents which should cause relay operation may be smaller under some conditions than the maximum load current under other conditions.

The interconnecting system is usually composed of long high-voltage transmission lines, capable of transmitting relatively large blocks of power. The high load capacity of these lines reduces the number of parallel lines necessary, thus making protection difficult. Also, the expense of substations or switching stations is high and their number is therefore correspondingly reduced. To reduce expense, the system may adopt the form of a triangle, or loop, only one of a pair of lines may be carried through a substation, or different routes may be followed by the various lines. In addition to these difficulties, later extensions invariably tend to complicate relay protection.

Pilot Wire Protection. To clear faults in the minimum time, theoretically, the best solution probably lies in the use of differential bus protection and pilot wire line protection. Fig. 1 illustrates a pilot wire scheme which has several advantages. This is a circulating current scheme and the burden imposed on the current transformers is quite low. In this method, open circuits on pilot wires put the relay in an operative condition for faults either external or internal to the section. This scheme is novel, in that four balancing resistors are used instead of three, with the result that balanced conditions are maintained irrespective of whether a through fault is phase-to-phase or phase-to-ground. This permits the use of ground relays having a low-current setting, thus increasing the sensitivity of the protection.

Although the pilot wire scheme of protection approaches very closely the ideal, the difficulty of installing and maintaining pilot wires prevents its use on all but the shortest transmission lines. The periodic tests, which are essential to all protective equipment, are rather intricate on this scheme. Another objection to this scheme is found in that additional relays must be installed for back-up protection.

Parallel Line Protection. The desirable characteristics of the selective differential relay, (as used in Fig. 1), makes it suitable for protection of parallel lines provided there is a source of feed at each end. This relay operates under conditions of current unbalance to trip the breaker through which the heaviest current is flowing.

During conditions of single-line operation, the differential relay is usually rendered inoperative, and some

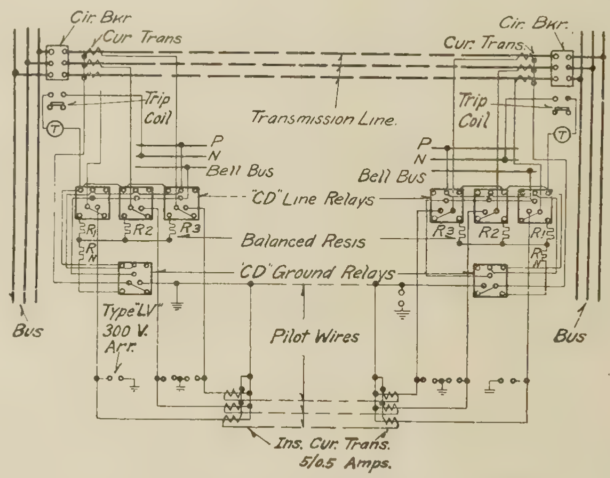

Fig. 1—Balanced-Current Pilot-Wire Scheme Using Selective Differential Relays

form of back-up relay is essential. The application of differential relays is therefore usually made in conjunction with back-up, over-current, or directional over-current relays, the differential relays being inoperative during conditions of single-line operation. The back-up relays also furnish protection against bus faults. Therefore, balanced protection on parallel feeders approaches the protection afforded by pilot wires during conditions of parallel operation, but for faults within the section during single-line operating conditions, a long time is required for clearing, since selective settings are then used.

Under many operating conditions, a substation may have a connected source of feed-back into a fault, so that directional back-up protection is necessary during conditions of single-line operation. For this application, cross-connected, over-current, directional relays are applicable. This scheme is shown in Fig. 2A. The relays each consist of a directional element and an

over-current element, the contacts of the two elements being connected in series. The common points of these two sets of contacts is brought out of the relay case by a separate stud. The directional elements in both sets are practically instantaneous. The over-current element in one set of relays is given a short-time, low-current setting, and the over-current element

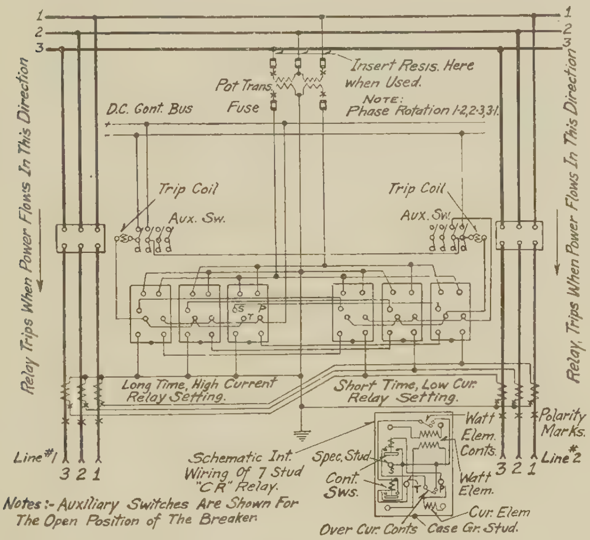

Fig. 2a—Protection for a Pair of Parallel Lines

Effective for both parallel and single-line operation, using directional over-current relays

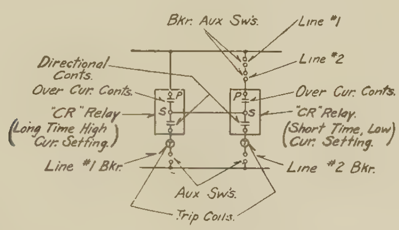

Fig. 2b—Schematic Diagram of Trip Circuits of Fig. 4a

in the other set is given a long-time, high-current setting.

Fig. 2b shows the schematic diagram of the trip circuits.

The objections to the use of balanced protection lie in the fact that the relays which give quick clearing of faults afford no back-up or bus protection, and extra relays must be used for this purpose. Also, under conditions of single-line operation, long-time is required for clearing a fault on the line remaining in service. The cross-connections are relatively complicated, and testing and checking is made more difficult. In addition to these objections, the cross-connected directional relay protective scheme requires a source of potential. This objection, however, is not serious, since a suitable low-voltage set of potential transformer is nearly always available and the secondary potentials from these potential transformers may be used.

Impedance Relays. The application of impedance relays satisfies many of the demands placed on protective equipment for interconnections. Particularly is it true that rendering the system more complex does not necessitate increased time for operation, nor does the relay place limitations on the permissible system connections. The time required for clearing faults does not become cumulative. Bus protection, quick clearing of faults, and single-line protection are all secured.

Used on transmission lines, irrespective of whether parallel lines or single lines are in service, the impedance relay will clear faults as quickly as will balanced relays, when faults are located near the extremities of the line. With a fault in the center of the section, the impedance relays will clear in approximately four-tenths of a second; and balanced relays, under the best operating conditions, may clear these faults faster than will the impedance relay. On the other hand, the impedance relay operates effectively irrespective of whether one or two lines are connected in parallel and is independent of other changes in operating conditions.

Fig. 3 shows a typical connection of impedance relays.

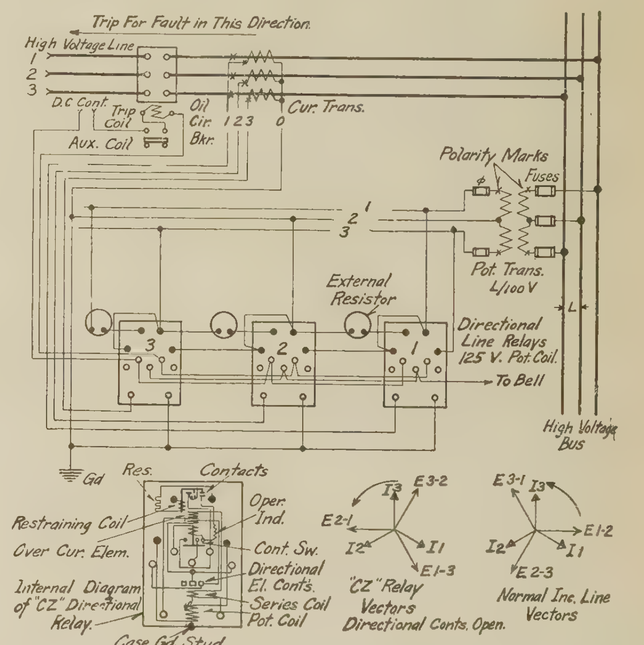

Fig. 3—Typical Connection Diagram of Impedance Relays Applied to Sectionalize Wire-to-Wire Faults on Transmission Sections

When applied in this manner, the relays protect against phase-to-phase faults only and constitute only a small measure of protection against phase-to-ground faults. The use of potential is required with the impedance relay, but this objection may be overcome, as previously mentioned, by using low-voltage potential transformers. Another method of obtaining correct potential for relays when high-voltage potential transformers are not available is covered later.

Relay Operation with Low Current Faults. To meet fully the requirements of relay equipment applicable to inter-connections, the relays must operate on fault currents, which may be less than full load current. In order to satisfy this demand, a fault-detecting device has been developed,—a device composed of an undervoltage and an over-current element connected in each phase. The contacts of these elements (two per phase or a total of six) are connected in parallel, so that any conditions of either undervoltage or over-current will cause the relay contacts to be closed. In applying this device, the over-current element is set to operate at a current value corresponding to approximately 125 per cent of the maximum load which is expected in practise. Therefore, the current relays should never operate unless heavy fault currents are flowing. The undervoltage device is set for, say, 75 per cent of normal voltage.

The principle of operation of this combination is quite simple. If the distribution of generating capacity is such that the bus voltage will not drop below approximately 75 per cent of normal, the current to a fault near the bus must necessarily be high. On the other hand, if the magnitude and distribution of the generating capacity is such as to permit only a small current to flow to the fault, the bus voltages near this fault must necessarily be very low. As a result, either the over-current or the undervoltage relay is sure to operate with a fault so located as to demand their operation for proper clearing. In order to fully meet the various conditions existing in practise, both the over-current and the undervoltage relays have a suitable range of adjustment.

Fig. 4 shows one application of the fault detecting relay. In this application, operation of the line protective relay under heavy load conditions is prevented because the current coils of the relay are short-circuited. The fault detecting relays, when deenergized, permit the back contacts of the auxiliary relay to short-circuit the line relays. The fault conditions on the system cause the contacts of one or more elements of the fault detector relays to close, thus energizing the auxiliary relay and removing the short circuit from the impedance relay. Then the impedance relay is permitted to function and will operate if the impedance between the station bus and the fault is sufficiently low.

Thus, after a fault on the system has occurred, all impedance relays on the system are connected into service, permitting the one nearest the fault to open the circuit breakers on the faulty section. Since the impedance relay current coils are normally short-circuited, they may be set on the one-ampere tap although maximum load currents may be five amperes. This scheme has a second advantage, in that the relay burden is removed from the current transformers except under fault conditions.

Phase-to-Ground Fault Protection

Advantages of Ground Relays. The advantages resulting from application of ground relays for protection of transmission circuits are now well established. These advantages may be briefly itemized as follows:

a. Ground relays operate on residual currents and so may be given a more sensitive setting than can the relays protecting against line-to-line faults.

b. These sensitive settings are necessary because the magnitude of ground currents may be reduced below that value necessary to cause prompt operation of the relays normally protecting against line-to-line faults either by impedance in the neutral connections of the transformer banks by resistance at the point of fault or by the high earth return impedance.

c. A high percentage of faults on transmission line cause ground current to flow. Thus, the residual relay, with its relatively quick timing, increases the speed of clearing a large percentage of the faults.

d. When this relay is used, those protecting against phase-to-phase faults act as a back-up protection.

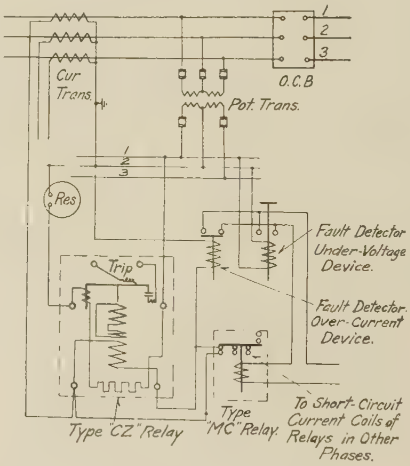

Fig. 4—Application of Impedance Relays for Protecting Systems where Fault Current is Less than Full-Load Current

e. On certain types of system connections, an inverse-time over-current residual-current relay may be used and the distribution of ground current is such as to cause the relays closest to the fault to operate always very quickly.

Distribution of Residual Currents. On a system where the neutrals of all equipments are solidly grounded, the distribution and magnitude of fault currents differ depending on the type of faults. As a result of this, the study of phase-to-phase fault conditions may not be sufficient to permit accurate setting of relays used for protection against phase-to-ground faults. In many cases, a special study is required to determine the distribution of ground current, and this study quite frequently shows that protective equipment which is superior to that available for phase-to-phase fault may be applied for protection against phase-to-ground faults.

The Method of Symmetrical Components (phase

sequence) for analyzing fault conditions on transmission lines,—developed by C. L. Fortescue,[2] simplifies this otherwise complicated problem. The magnitude of residual currents may be determined with little more effort than that required for the determination of the positive phase sequence quantities corresponding to a three-phase fault. To show the desirability of

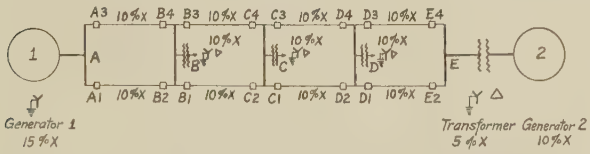

FIG. 5—SYSTEM LAYOUT FOR ILLUSTRATING CURRENT DISTRIBUTION

making this separate study, and to illustrate application of ground relays, a few results of a study of a simple system are given.

The system used in these calculations is shown in Fig. 5. At one end of the system a generator is shown connected through a transformer bank, and at the other end of the system a generator is connected directly to the system. This has been done to illustrate that some difference exists depending on whether the generator is connected directly to the system or through a trans-

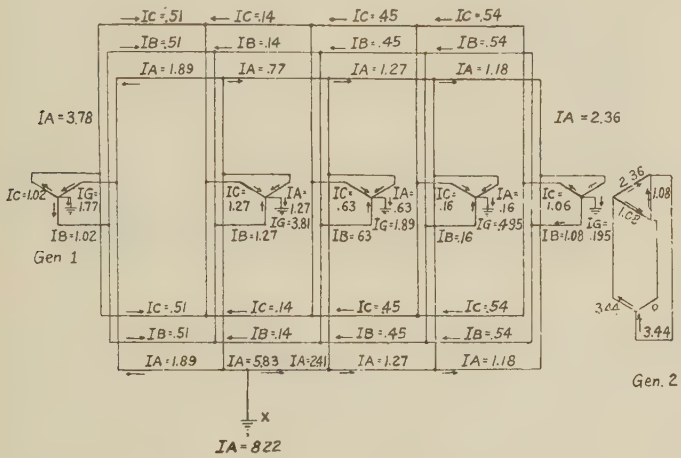

FIG. 6—FAULT-CURRENT DISTRIBUTION DIAGRAM

Showing effect of grounding the neutral of substation power banks

former bank. The reactance of both the generator alone, and of the generator in combination feeding through the transformer bank has a total impedance of 15 per cent.

The transformer banks at the substations are in some cases, assumed to be connected star-delta with solidly grounded neutrals, so that they have the effect of grounding transformer banks on the system. To illustrate the effect of these banks as compared to delta-connected banks, certain calculations have also been made with the transformer banks disconnected from the substation busses.

2. A. I. E. E. TRANS., 1918, Vol. XXXVII, Part 2, p. 1027.

Fig. 6 illustrates the distribution of conductor currents throughout the system with a fault located between Stations B and C on phase A conductor of one of these parallel lines. Fig. 7 illustrates the distribution of conductor currents for a similar fault; but

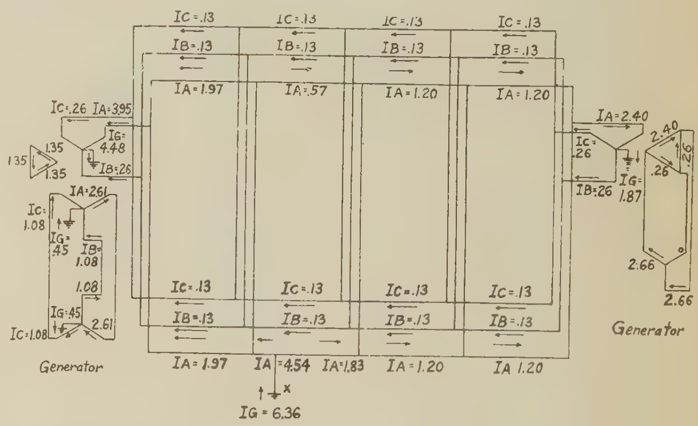

FIG. 7—FAULT-CURRENT DISTRIBUTION DIAGRAM

Conditions identical with those shown in Fig. 10 except that substation transformers have been removed. Generator No. 1 has been replaced by an equivalent impedance

here, the substation transformer banks are assumed to be delta-delta connected. I_A, I_B, and I_C are the phase currents and those marked I_G are the generator and transformer bank neutral currents.

By comparing these two figures it will be seen that the magnitude and distribution of conductor current is radically changed, depending upon whether the substation transformer bank neutrals are solidly grounded

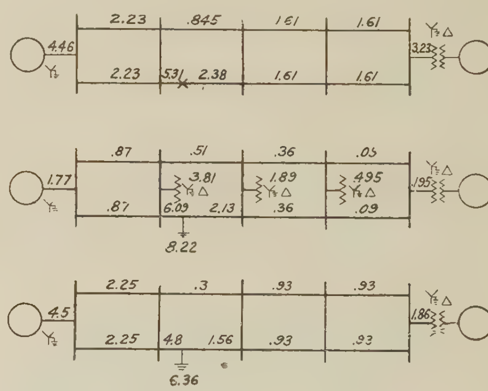

FIG. 8—A COMPARISON OF FAULT-CURRENT DISTRIBUTION WITH IDENTICAL FAULT LOCATION

A—Three-phase fault-current distribution
B—Residual-current distribution with grounding transformers on a line-to-ground fault
C—Residual-current distribution without transformer banks on a line-to-ground fault

or not. In Fig. 6 the biggest portion of the ground current flows through the neutrals of the substation transformer banks adjacent to the fault. The banks farthest from the fault pass only a small amount of residual current, the magnitude decreasing as the distance to the fault increases. This residual current distribution will vary depending upon the relative

impedances of the transformer banks and transmission lines to the flow of zero-phase sequence current, and therefore demands special study.

Fig. 8 illustrates the difference in current distribution, depending on the type of faults and type of system. Fig. 8A shows the distribution of current for a three-phase fault. Fig. 8B illustrates the distribution of residual current for a fault located as shown on Fig. 6. The values shown in Fig. 8B are equal to three times the zero-phase sequence current. They

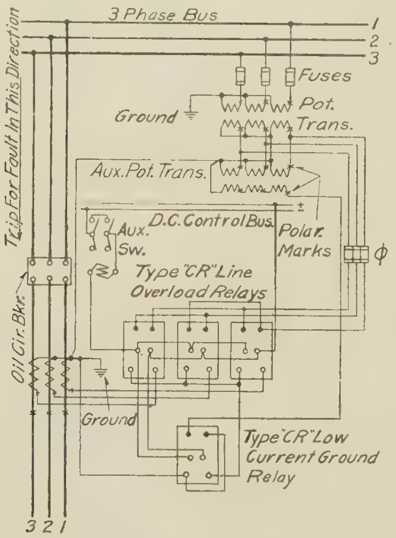

Fig. 9—Directional Line and Ground Protection for One Three-Phase Line

are therefore the residual currents which would flow through the relay coils of the ground relays. It is to be noted that here the current in the relays on the faulty section is much greater than that in any other relays on the system. This is true irrespective of whether the lines are connected in parallel or whether one line is disconnected from service. Fig. 8C illustrates the residual current which would flow through the ground relay coils for a fault located as shown on Fig. 7.

Figs. 8A and 8C resemble each other very closely, the only difference being due to the increased reactance of the transmission line for phase-to-ground fault conditions over the reactance for a three-phase fault. As a result, on systems corresponding to Fig. 8C, the same system of relaying has been generally used for protection against phase-to-ground fault as is used for protection against phase-to-phase faults. The greatest advantage of ground relays may be obtained from the current distribution as shown in Fig. 8B. Here, definite advantages in selectivity, speed of clearing, and sensitivity may be obtained by the use of ground relays. A comparison of Figs. 8A and 8B will illustrate that the use of ground relays with proper characteristics would assist materially in securing suitable relay protection on a system of this type.

Definite-Time Ground Relays. Fig. 9 shows a diagram of connections for relays suited to the protection of a system with current distribution similar to that shown in Fig. 8B. This diagram shows selective relays applied as for protection against single-line operation. Standard directional relays are used for protection against phase-to-phase faults. The directional ground relay is of the low energy type with low-current setting. It also differs from the directional relays used for protection against phase-to-phase faults, in that maximum torque is obtained on the directional element of the ground relay when the relay current lags behind the relay potential. For parallel lines, balanced protection is desirable.

Fig. 10 shows the distribution of residual currents in the system as shown in Fig. 7, except that a fault impedance of 10 per cent resistance is present. The vector diagrams at the various substation busses and at the faults are shown. As may be seen from this, the phase displacement between the residual voltage and the residual current on this system will always be

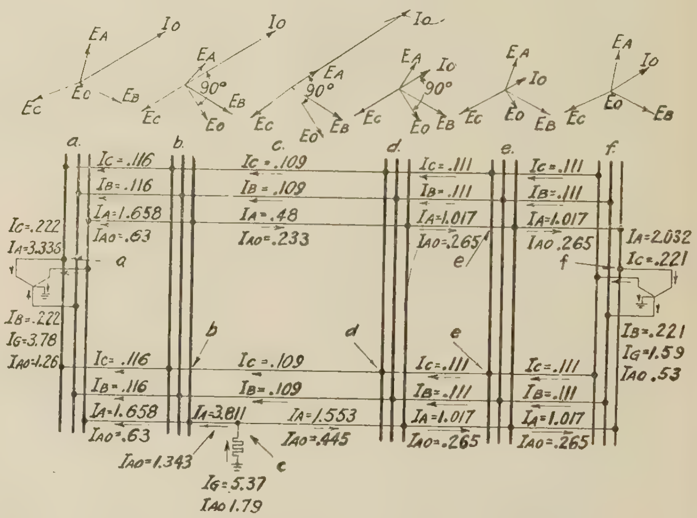

Fig. 10—Current Distribution and Vector Relations Existing Within Relays

For system as shown in Fig. 11 and with a 10 per cent fault resistance

90 deg. so long as the system impedance is pure reactance.

If this were true for all systems, the theoretically correct relay to use would be one in which the maximum torque is obtained when there is a phase displacement of 90 deg. between voltage and current. On the actual system, resistance is present in the transmission lines and equipment. This will tend to decrease the displacement angle. Under conditions where the phase-to-ground fault has no resistance and the neutrals of the transformer banks or generators are grounded through a high resistance, it is theoretically possible for the residual current and the residual voltage to be in phase, so that the unity power factor condition should cause the maximum torque. It is therefore desirable that this type of relay should secure the maximum

torque at some angle lying in between zero and 90 deg. so as to be applicable to any system conditions. Until recently relays commonly used for this purpose have had approximately true watt characteristics, and it was possible for these relays to operate improperly under

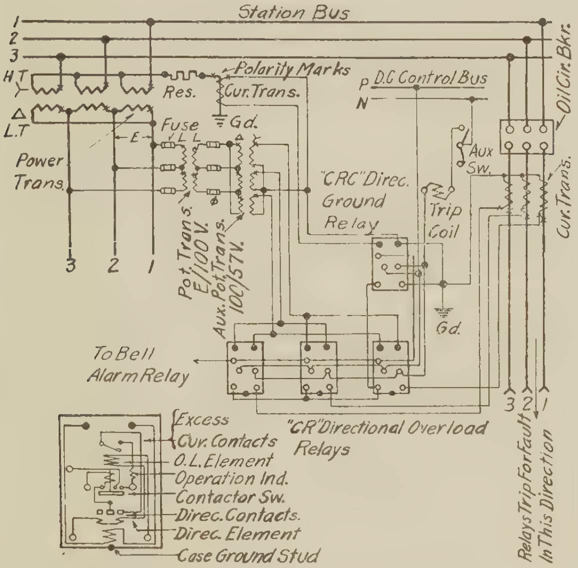

Fig. 11—Directional Over-Load and Directional Ground Protection

Using definite time, residual, over-current relays and low-tension potential transformers

Rear view "CRC" directional ground relay is shown in lower left-hand corner

certain fault conditions. Where such a relay is now in use, it may be desirable to insert a phase shifting device in its potential circuit so as to obtain the proper phase relation.

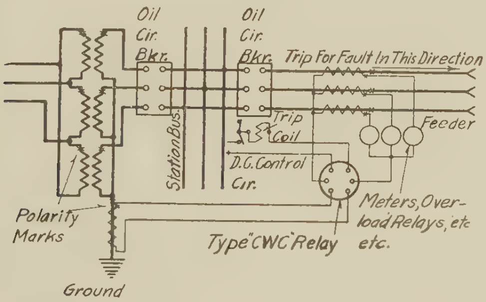

Fig. 12—Typical Diagram of Connections for Ground Protection Using the Inverse Time, Residual, Over-Current, Ground Relay

In order to avoid using high-voltage potential transformers, the connections shown in Fig. 11 may be employed. As illustrated by Figs. 6 and 8B, the current flowing through the fault is largely supplied through the neutral of the transformer bank nearest the fault. Thus, instead of using a potential as shown in Fig. 9, the neutral current from the power banks may be used to determine the relative direction of current flow in a line. The currents in the line and in the neutral of the transformer bank are approximately in phase, so that the relay should be so designed as to have the maximum torque when the currents in the residual circuit of the current transformers and in the

Fig. 13—Product of Transformer Bank Neutral Currents and Residual Line Currents

For any fault location and for phase-to-ground faults for the system shown on Fig. 9

neutral connection of the power banks are in phase. The connections shown in either Fig. 9 or Fig. 11 are equally good in determining the location of the fault.

Inverse-Time Ground Relays. The diagram shown in Fig. 12 is an alternative for, and under certain conditions, an improvement over that shown in Fig. 11. This scheme was first devised and put into service by Mr. Roy Wilkins.[3] The residual relays used here are inherently directional and in addition, operate with an inverse characteristic that is quite suitable for systems where the neutrals of all transformer banks are solidly grounded, as illustrated in Fig. 8B. Fig. 13 shows the operating torque on the relays for the system as shown in Fig. 6. The curves plotted in Fig. 13 are the products of the current in the transformer bank times the current in the line at any point on the system. This is the product which would tend to operate the residual current relay when connected as shown in Fig. 12. The operating tendency of the relay de-

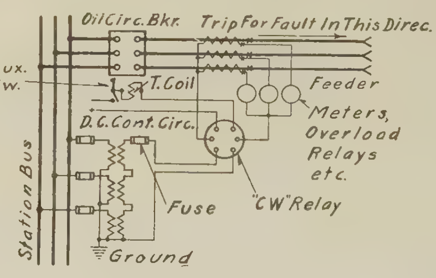

Fig. 14—Typical Diagram of Connections for the Residual Volt-Ampere Relay

creases rapidly as the fault approaches the adjacent substation bus, so that the quickest acting relay is that which is closest to the fault. In this respect, the relay has the characteristic of the impedance relay.

3. *Electrical World*, November 22, 1924, p. 1101.

After the breaker closest to the fault has cleared, the current through the relay on the far end of the faulty section increases and causes increased operating torque.

A modification of the connections shown in Fig. 12 is that shown in Fig. 14. Here, a volt-ampere relay is used. The relay depends upon the principle that the product of the residual current and the residual voltage is greatest when the fault is close to the relay, with the result that the relay closest to the fault operates fastest. In addition to this, the relay is directional.

On a system as shown in Fig. 8C, the residual volt-

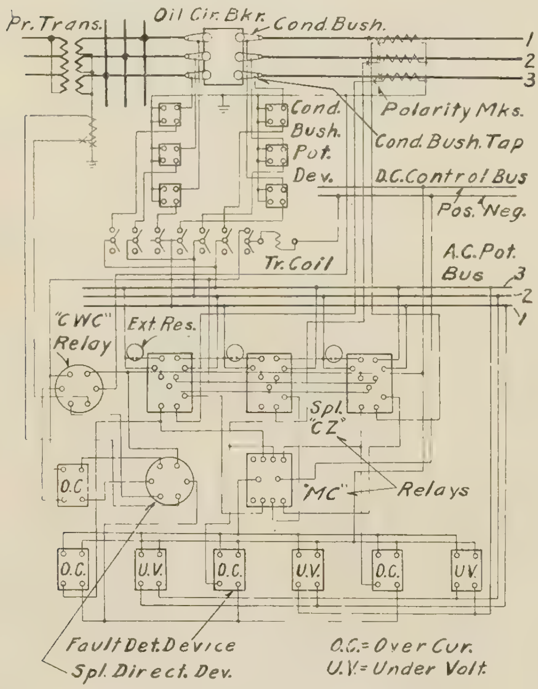

Fig. 15A—Diagram Showing Connections for a Complete Relay Scheme Applicable to a Complex Interconnecting System

age, or three times the zero phase sequence voltage, increases from each end of the transmission line to the fault. The vector diagrams given in Fig. 10 illustrate the largest product closest to the fault.

The operating forces on this relay would be similar to that shown in Fig. 13 and would apply to the system shown in Fig. 5. Quite clearly, the relay closest to the fault would operate much faster than any other relay on the system. This is true if the relay is so designed that the torque is proportional to the product of zero phase sequence currents and potentials as mentioned above in the discussion of the phase relations in the directional relay in connection with Fig. 10.

This volt-ampere product may be obtained quite accurately by an approximation. The unbalanced voltage, or zero phase sequence voltage which is used on the relay, is usually due to the drop through transformer banks plus transmission lines up to the relay. The phase angle between this voltage and the residual current may be as much as 80 deg. Taking this as the maximum, one may set the relay so as to secure the maximum torque when the phase displacement is 55 deg. The conditions of the system may then change so that the phase displacement varies from 80 deg. (0.174 power factor) to 30 deg. (0.867 power factor) without introducing a volt-ampere error of more than 10 per cent.

A Typical Relay Installation

Fig. 15A represents a composite picture of relays suitable for application to a system as shown in Fig. 5. Impedance relays are used for protection against phase-to-phase faults, so that the maximum time of relay operation is three-quarters of a second. The average time will be much less than that and will approach very closely the timing obtained by parallel-line protection.

Potential for these devices may be obtained from low-voltage potential transformers with suitable compensators, from high-voltage potential transformers, or from a tap on the condenser bushing of the circuit breaker. The voltage thus obtained is higher than desirable, and must be reduced and its phase shifted by means of a small stepdown transformer and network, according to a method developed by J. F. Peters.

The load conditions on the system here shown are assumed to be such that fault currents of less than full-load magnitude must be guarded against. For this reason, low-current setting impedance relays are used and these relays are normally short-circuited by the

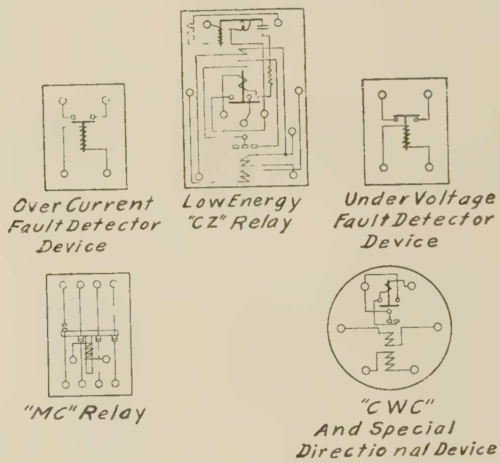

Fig. 15B—Internal Wiring Diagrams

auxiliary relay contacts. The fault detector relays operate under conditions of either over-current or under-voltage to remove this short circuit from the impedance relay coils. The residual relay is used to obtain the selective timing necessary for protection against phase-to-ground fault. In addition to the inverse time residual relay, an instantaneous over-current relay has been added to increase the speed of operation over that afforded by the residual relay for certain fault conditions. For this particular application, a directional instantaneous over-current relay was necessary and the directional element has therefore been included in a separate case.

This protective scheme compares very favorably with the ideal system for interconnections as previously specified. It has the following advantages:

1. The quick clearing of faults.
2. System operating set-up does not affect relay operation.
3. Relay system permits unlimited system extensions and revisions without necessitating increased relay timing.
4. The relay system should necessitate little or no change on the installed relay equipment protecting the individual systems combined by the interconnection.
5. Relays afford protection against bus faults.
6. Back-up protection against faulty operation of relays or breakers is afforded by this system of protection.
7. High-voltage potential transformers are not required. The breaker equipped with bushing type current transformers supplies both current and potential for the relays. Potential may also be obtained from low-voltage potential transformers.
8. The relay equipment is simple, standard, and economical.

BEAM OF ELECTRONS SHOWS DIFFRACTION EFFECTS IN SCATTERING EXPERIMENTS

REPORTED BY DR. DAVISSON TO PHYSICISTS

Experiments conducted at the Bell Telephone Laboratories in New York, N. Y., have brought to light the fact that a moving beam of electrons partakes in some way of the nature of a wave motion. The work there by Dr. C. J. Davisson and Dr. L. H. Germer shows that electrons when reflected from a single crystal of nickel scatter in certain definite directions in a manner analogous to the crystal scattering of a beam of X-rays.

"The scattering of X-rays by a crystal results in the production of strong scattered beams in just certain directions," Dr. Davisson stated, "and this fact has been explained always on the hypotheses that X-rays are an electromagnetic wave disturbance of the same sort as radio waves and visible light. Our experiments show that a beam of electrons gives these same effects. The inference seems to be that there is some sort of a wave-motion associated with the motion of a beam of electrons."

The experiments showed that the observed wave length of the electron beam was exactly that which is predicted by the quantum theory as developed by L. De Broglie, E. Schroedinger and others. This wavelength is numerically equal to Planck's constant of action divided by the momentum of the electron. Describing the experimental method, Dr. Davisson explained that the source of the electrons was a hot filament just as in ordinary radio thermionic tubes. These were accelerated by a positive grid voltage which could be varied at will. The voltages used ranged from about 50 to 375. The beam of electrons impinged on a nickel crystal, and some of them were absorbed in it; others were scattered back from the surface of the crystal. Of those scattered back, some come back without having lost any speed. A little collecting device was arranged so that it could be moved to various positions in front of the crystal to find how many electrons were scattered in the various directions without loss of speed.

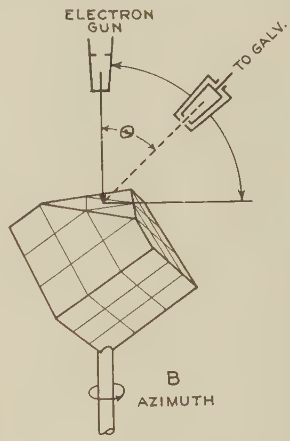

Fig. 1

"The situation confronting physicists with regard to electrons is now something like the dilemma confronting the theory of light," the speaker declared. "For many years all the facts concerning light could be explained by assuming it to be simply a wave motion. Then the quantum theory, in the hands of Planck, Einstein, and A. H. Compton, showed that radiation had to be regarded also as having something corpuscular about it. Similarly, for many years electrons were believed to be simply corpuscles of negative electricity. But now, recent developments in quantum theory, confirmed by these experiments, show that there is something wave-like about them."

A full account of this work appears in the December 1927, *Physical Review* and in the January 1928, *Bell System Technical Journal.*

Fig. 1 shows the arrangement for causing a stream of electrons to strike the nickel incidence and the collector which could be moved around to measure the numbers of electrons scattered in different directions;

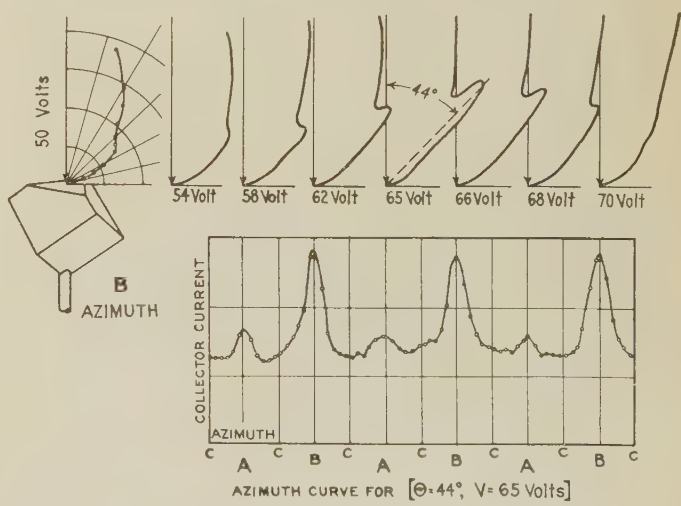

Fig. 2

and Fig. 2, a typical set of experimental curves showing the gradual development of a spur of diffracted electrons at 50 deg. and 54 volts. The power curves show how this diffracted beam depends on the azimuth of the collector relative to the axes of the crystal structure.

Institute and Related Activities

Winter Convention Has Notable Program

Great interest has developed in the Winter Convention of the Institute which will be held in New York City, February 13-17, with headquarters at the Engineering Societies Building. The technical sessions are especially noteworthy and in addition, there will be lectures, inspection trips, medal presentations and social features.

Technical Sessions

The technical papers and lectures will include as subjects, electrophysics, dielectrics, operation of interconnected power systems, insulators, magnetism, electrical machinery, transatlantic telephony, telegraphy, loud speakers, automatic substations, control and protective apparatus, synchronizing devices and arc welding.

Details of the technical sessions are published in the accompanying program of events.

Symposium on Interconnection

Great interest is being manifested in the session on Tuesday morning, February 14, on the subject of operating interconnected power systems. This subject will be presented in papers by four outstanding engineering executives representative of different practises in four parts of the country. Prepared discussions will be presented by several other well versed engineers.

Telephone Communication with London

Telephone communication with the British Institution of Electrical Engineers, meeting simultaneously in London, is to be one of the outstanding features of the convention. This event is scheduled for Thursday morning, February 16. The session will open with two papers on transatlantic telephony as announced in the accompanying program.

Following these papers there will be an exchange of greetings over the New York-London radiotelephone circuit between Bancroft Gherardi, President of the American Institute of Electrical Engineers, and Archibald Page, President of the British Institution of Electrical Engineers. Greetings will also be exchanged between Dr. F. B. Jewett, Vice President of the American Telephone and Telegraph Company, and President of the Bell Telephone Laboratories, in charge of the development work done in this country leading to the establishment of the transatlantic service, and Colonel T. F. Purves, Chief Engineer of the British Post Office, who has charge of the development work done in England in this matter.

Arrangements are being made for these exchanges of greetings to be heard by those present at the session of the A. I. E. E. in New York, and also by the members of the Institution of Electrical Engineers, who will be having a regular afternoon meeting in London, simultaneous with the New York meeting.

Following this two more technical papers will be presented as shown in the program.

Lecture by Dr. Swann

An outstanding event will be a lecture on "The Earth's Electric Charge," to be given by Dr. W. F. G. Swann on Monday evening, February 13. Dr. Swann, who is Director of the Bartol Research Foundation of the Franklin Institute, is an entertaining speaker as well as a high authority on subjects pertaining to electrophysics.

Lecture by Dr. Norinder

Dr. Harold Norinder, of Upsala, Sweden, well known in this country for his studies of lightning discharges and other matters, will furnish one of the interesting points of the meeting. He will deliver a lecture in the session on the afternoon of February 14, his subject being "The Cathode Oscillograph as Used in the Study of Lightning and Other Surges on Transmission Lines."

John Fritz and Edison Medals

Two of the most highly desired rewards for engineering accomplishments will be presented on the evening of Wednesday, February 15. The John Fritz Medal will be presented to General John J. Carty, and the Edison Medal to Dr. William D. Coolidge. The presentation ceremonies will include an address by Dr. Michael I. Pupin who will outline the achievements of Dr. Coolidge; the presentation of the Edison Medal by President Gherardi of the American Institute of Electrical Engineers, and the response of the medalist; the announcement of the John Fritz Medal award by Chairman J. V. W. Reynders of the Board of Award; an outline of the achievements of General Carty by Bancroft Gherardi; the presentation of the John Fritz Medal by Robert Ridgway, Chairman of the Board when the award was made, and the response of General Carty.

Details of the award of the John Fritz Medal were published in the November Journal, page 1290. An announcement of the award of the Edison Medal is published in the January Journal, page 75.

Inspection Trips

Quite a number of inspection trips have been planned, most of which will be taken on Thursday afternoon, February 16, though some of the places may be visited at other times by prearrangement. Among the trips which are planned are those to the following places.

132-kv. cable installation at Hell Gate Station of the United Electric Light and Power Company.

"Armor-Clad" switchgear—East 172nd street station of the New York Edison Company having only this enclosed type of construction.

System operators switchboard, Waterside Station, New York Edison Company.

132-kv. switching station (Hudson Station) and Kearny Station of Public Service Electric & Gas Company.

Hudson Avenue Station and A-C. network equipment of Brooklyn Edison Company.

East River Station of New York Edison Company.

Broadcasting studio of National Broadcasting Company.

A-c. network switches of United Electric Light & Power Company.

The Roxy Theater.

The Electrical Testing Laboratories.

Demonstration of television—Bell Telephone Laboratories.

Telephotography—American Telephone & Telegraph Company.

Steamship *Mauretania*.

The Holland Tunnel.

Ford Assembly plant, Kearny, N. J.

Cable plant of Western Electric Co.

Dinner-Dance

That enjoyable social function, the annual dinner-dance, will be held on the evening of Thursday, February 16, in the main ball room of the Hotel Astor. This is an institution which needs no recommendation. It is sufficient to say that it will be held in

the spacious Astor ball room, the meal will be excellent and "The Vagabonds," one of the best dance orchestras in New York, will furnish the music. Tickets will be $6.00 per person.

The Smoker

A delightfully informal event will be the Smoker, to be held on Tuesday evening, February 14, in the Belvedere of the Hotel Astor. Every effort is being made to make the program for this evening unusually attractive, and at the same time to eliminate the confusion and crowding which have occurred in some former smokers. The committee feels that this can be done and without an increase in the former price of $2.00 per person.

Reduced Railroad Rates

Special railroad rates will be available to out-of-town visitors to the convention, under the certificate plan. Under this plan, each person should request a certificate when purchasing a one-way ticket to New York. Presentation of this certificate at Convention headquarters will entitle the holder to a half-rate fare for the return trip over the same route, provided 250 certificates are registered at the Convention.

When purchasing tickets members or guests should advise their ticket agents that they will attend the A. I. E. E. Convention, and should ask for the certificates. Families of members attending the Convention are entitled to certificates also. On a few limited trains the return tickets purchased at reduced rates will not be honored. Tickets must be purchased within a limited number of days prior to the meeting and return tickets must be used within a limited time after the meeting. The limiting dates depend upon the location of the purchaser. Information on these and other details may be obtained from ticket agents. Immediately upon arrival in New York, certificates should be deposited with the endorsing officer at Convention headquarters.

All Visitors Should Get Certificates

Everyone should obtain a certificate, whether he will use it or not, for failure to do so may deprive others coming long distances of the saving in railroad fare made possible by this provision.

Hotel Reservations

Requests for hotel reservations should be made at as early a date as possible. Application should be made directly to the desired hotel.

Convention Committees

The plans for the meeting are being handled by the following general committee and subcommittees:

General Committee—G. L. Knight, Chairman; J. B. Bassett, H. P. Charlesworth, H. W. Drake, W. S. Gorsuch, H. A. Kider, E. B. Meyer, L. W. W. Morrow and R. H. Tapscott.

Entertainment Committee—J. B. Bassett, Chairman; L. B. Bonnett, H. C. Dean, J. F. Fairman, A. H. Inglis, C. R. Jones and A. H. Kehoe.

Dinner-Dance Committee—H. C. Dean, Chairman; A. B. Clark, C. R. Jones, J. F. Kelley and F. A. Muschenheim.

Smoker Committee—J. F. Fairman, Chairman; R. E. Dennis, H. W. Drake and W. S. Gorsuch.

Inspection Trip Committee—A. H. Inglis, Chairman; W. B. Kirke, L. W. McCullough, W. R. Smith and F. Zogbaum.

Program

Monday Morning, February 13

Registration.
Committee Meetings.

MONDAY, 2:00 P. M.

Electrophysics and Dielectrics

Technical Session, under auspices of Committee on Electrophysics, Vladimir Karapetoff, Chairman.

Surge Impulse Breakdown of Air, J. J. Torok, Westinghouse Electric & Mfg. Co.

Influence of Internal Vacua and Ionization on the Life Duration of Paper-Insulated, High-Tension Cables, Alexander Smouroff and L. Mashkileison, Electrotechnical Institute of Leningrad.

Approximate Solution for Electrical Networks, E. A. Guillemin, Massachusetts Institute of Technology.

The Boltzmann-Hopkinson Principle of Superposition, F. D. Murnaghan, Johns Hopkins University.

MONDAY, 8:00 P. M.

LECTURE

The Earth's Electric Charge, W. F. G. Swann, Director of Bartol Research Foundation, Franklin Institute.

TUESDAY, 9:30 A. M.

Interconnection and Its Effect on Power Development

Technical Session, under auspices of Committee on Power Generation, W. S. Gorsuch, Chairman.

The following papers and discussion constitute a symposium on present-day practise and new developments of interconnection in various parts of the United States. Some of the points to be considered are: (a) Effect on Plant Capacity and Size of Generating Units; (b) Economics of Operation; (c) Operating Features; (d) Stability and Reliability; (e) Load Dispatching and Load Control; (f) Technique of Interconnection Operation; (g) Physical Facts as to Interstate Power.

The Conowingo-Hydro-Electric Project of the Philadelphia Electric Company's System—with Particular Reference to Interconnection, W. C.L. Eglin, The Philadelphia Electric Co.

Progress and Problems from Interconnection in the Southeastern States, W. E. Mitchell, Georgia Power Co.

Some Aspects of Pacific Coast Interconnections, P. M. Downing, Pacific Gas & Electric Co.

Interconnection and Power Development in Chicago and the Middlewest, H. B. Gear, Commonwealth Edison Co.

Discussion of the papers and the subject of interconnection in general will be presented by the following:

Charles L. Edgar, Edison Electric Illuminating Company of Boston.
A. C. Marshall, The Detroit Edison Co.
John W. Lieb, New York Edison Company.
James Lyman, Sargent & Lundy ,Inc.
Farley Osgood, Consulting Engineer.
E. C. Stone, Duquesne Light Co.
G. N. Tidd, American Gas & Electric Co.
L. W. W. Morrow, *Electrical World.*
W. S. Lee, Southern Power Co.
R. F. Schuchardt, Commonwealth Edison Co.
C. F. Hirshfeld, Detroit Edison Co.
F. A. Allner, Pennsylvania Water & Power Co.

TUESDAY, 2:00 P. M.

Technical Session on Miscellaneous Subjects

The Saturation Permeameter, S. L. Gokhale, General Electric Co.

Manufacture and Magnetic Properties of Compressed Powdered Permalloy, W. J. Shackelton, Bell Telephone Laboratories, and I. G. Barber, Western Electric Co.

Effect of Humidity on Dry Flashover Potential of Pin-Type Insulators, J. T. Littleton, Jr., and W. W. Shaver, Corning Glass Works.

The Cathode Oscillograph as Used in the Study of Lightning and Other Surges on Transmission Lines, Lecture by Harold Norinder.

TUESDAY, 8:00 P. M.

Smoker and Entertainment

WEDNESDAY, 10:00 A. M.

Electrical Machinery

Technical Session, under auspices of Committee on Electrical Machinery, F. D. Newbury, Chairman.

Synchronous Machines—IV, R. E. Doherty and C. A. Nickle, General Electric Co.

Calculation of Armature Reactance of Synchronous Machines, P. L. Alger, General Electric Co.

Reactances of Synchronous Machines, R. H. Park and B. L. Robertson, General Electric Co.

The Thermal Volume Meter, C. J. Fechheimer and G. W. Penney, Westinghouse Electric & Mfg. Co.

Wednesday, 2:00 p. m.

Electrical Machinery

Technical Session, under the auspices of Committee on Electrical Machinery, F. D. Newbury, Chairman.

Recent Improvements in Turbine Generators, S. L. Henderson and C. R. Soderberg, Westinghouse Electric & Mfg. Co.

Design and Application of Two-Pole Synchronous Motors, D. W. McLenegan and I. H. Summers, General Electric Co.

Heat Losses in the Conductors of a D-C. Armature, W. V. Lyon, E. Wayne and M. L. Henderson, Massachusetts Institute of Technology.

Effect of Transient Conditions on Application of D-C. Compound Motors, L. R. Ludwig, Westinghouse Electric & Mfg. Co.

Wednesday, 8:30 p. m.

Presentation of John Fritz and Edison Medals.

Thursday, 9:30 a. m.

Communication

Technical Session, under auspices of Committee on Communication, H. W. Drake, Chairman.

Transatlantic Telephony—The Technical Problem, O. B. Blackwell, American Telephone & Telegraph Co.

Transatlantic Telephony—The Operating Problem, K. W. Waterson, American Telephone & Telegraph Co.

Following these papers there will be an exchange of greetings over the New York-London radiotelephone circuit as described in detail in a foregoing paragraph.

Loud Speakers of High Efficiency and Load Capacity, C. R. Hanna, Westinghouse Electric & Mfg. Co.

Certain Topics of Telegraph Transmission Theory, H. B. Nyquist, American Telephone & Telephone Co.

Thursday, 1:30 and 2:30 p. m.

Inspection Trips.

Thursday, 7:30 p. m.

Dinner-Dance.

Friday, 10:00 a. m.

Control and Protective Equipment and Substations

Technical Session, under auspices of Committee on Protective Devices, F. L. Hunt, Chairman.

Automatic Control of Edison System, O. J. Rotty, United Electric Light and Power Co., and E. L. Hough, General Electric Co.

Protection of Supervisory Control Lines Against Overvoltage, Edward Beck, Westinghouse Electric & Mfg. Co.

1926 Lightning Experience on 132-Kv. Transmission Lines, Philip Sporn, American Gas & Electric Co.

Vacuum-Tube Synchronizing Equipment, T. A. E. Belt and N. Hoard, General Electric Co.

Use of Condenser Type Bushing in Synchronizing, E. E. Spracklen, Ohio Public Service Co., and D. E. Marshall and P. O. Langguth, Westinghouse Electric & Mfg. Co.

Friday, 2:00 p. m.

Arc Welding

Technical Session, under auspices of Committee on Electric Welding, J. C. Lincoln, Chairman.

Effects of Surface Materials on Metallic Arc-Welding Electrodes, J. B. Green, Fusion Welding Corp.

Arc Welding—Influence of Surrounding Atmosphere on the Arc, P. Alexander, General Electric Co.

Arc-Welded Structures and Bridges, A. M. Candy, Westinghouse Electric & Mfg. Co.

Welding and Manufacture of Large Electrical Apparatus, A. P. Wood, General Electric Co.

St. Louis Regional Meeting March 7-9, 1928

The Regional Meeting to be held in St. Louis, March 7-9, 1928, by the South Western District of the Institute, will offer many timely subjects in its technical program as well as very enjoyable social features. The Hotel Coronado has been chosen as an ideal headquarters for this meeting.

Technical Sessions

A selection of very interesting technical papers has been made for the meeting. The technical sessions will be divided into four meetings on the general subjects of electrical machinery, power systems (a and b), and communication. Only four papers are assigned to each session, with the idea of avoiding the crowding of too many papers into a single meeting, which often means the suppression of interesting and instructive discussion.

The titles of all papers are given in the accompanying program of events.

Inspection Trips

Thursday afternoon, March 8, has been set aside for inspection trips. These will include a visit to the new Cahokia steam generating station, with its large outdoor high-voltage substations. Trips will also be made to some of the unique automatic stations in St. Louis, which are of the railway type, the three-wire d-c. Edison type, and the straight a-c. type.

The various manufacturers of electrical apparatus will be open for inspection trips, as well as other industrial plants such as glass works, steel works, mines, etc.

The new Bell Telephone Bnilding, with automatic switching equipment and telephotographic apparatus will also be available for inspection.

Lecture and Entertainment

On Wednesday evening, March 7, there will be a special entertainment to be held at the Engineers' Club Building. The first part of the entertainment will consist of a popular talk by F. W. Peek, Jr., on "Lightning" well illustrated by lantern slides and moving pictures. This will be followed by music and other entertainment. An orchestra will be provided for those who care to dance and all the facilities of the Engineers' Club will be open to the guests. Refreshments will be served.

Dinner-Dance

On Thursday evening, March 8, a dinner-dance will be held in the Pa Lido of the Coronado Hotel.

There will be a very short address by Bancroft Gherardi, president of the Institute, followed by a well known humorist.

The remainder of the evening will be devoted to dancing, using the famous Coronado Pa Lido, together with its large orchestra and entertaining features.

PROGRAM OF SAINT LOUIS MEETING

WEDNESDAY MORNING, MARCH 7

Registration 9:00 a. m. Committee Meetings

Branch Conference and Student Technical Session 9:15 a. m.

PROFESSOR GEO. C. SHAAD, Presiding

WEDNESDAY, 12:15 P. M.

Combined luncheon with St. Louis Electrical Board of Trade. Speaker Bancroft Gherardi, president A. I. E. E., Statler Hotel Ball Room.

WEDNESDAY, 2:15 P. M.

HOTEL CORONADO

Technical Session on Electrical Machinery

A. E. BETTIS, Presiding

Address of Welcome, A. E. Bettis, Vice President, A. I. E. E. Southwestern District.

Remarks by National President, Bancroft Gherardi.

1. *Magnetic Leakage and Fringing-Flux Calculations*, W. L. Upson and E. L. Furth, Washington University.
2. *Squirrel-Cage Motors with Split Rings*, H. Weichsel, Wagner Electric Corp.
3. *Electric Equipment for Oil and Gas Locomotives*, A. H. Candee, Westinghouse Elec. and Mfg. Co.
4. *The Squirrel-Cage Motor*, J. L. Hamilton, Century Electric.

WEDNESDAY, 8:00 P. M.

Lecture and special entertainment, Engineers' Club Building. Music, dancing, games, refreshments.

The lecture is by F. W. Peek, Jr. of the Transformer Engineering Department, General Electric Company, Pittsfield, Mass. Subject "Lightning."

This is to be a popular talk, well illustrated with lantern slides and moving pictures. Ladies are invited.

THURSDAY MORNING, MARCH 8

Technical Session 9:15 a. m.

POWER SYSTEMS "A"

L. F. WOOLSTON, Presiding

5. *The Public Utility Laboratory and Its Relation to Service*, G. E. Meredith and D. D. Clark, Kansas City Power and Light Co.
6. *Recent Developments in the Application of Demand-Metering Equipment*, Stanley Stokes and Leslie V. Nelson, Union Electric Light and Power Co.
7. *Excitation Systems—Their Influence on Short Circuit and Maximum Power*, R. E. Doherty, General Electric Co.
8. *Voltage Regulators*, R. M. Carothers and C. A. Nickle, General Electric Co.

THURSDAY, 12:15 P. M.

Luncheon at Hotel Coronado.

THURSDAY AFTERNOON

Inspection trips arranged to suit the convenience of guests.

THURSDAY, 7:00 P. M.

Dinner-Dance in the Pa Lido of the Coronado Hotel.

FRIDAY, MARCH 9

Technical Session 9:15 a. m.

POWER SYSTEMS "B"

S. M. DE CAMP, Presiding

9. *Development of Impedance Relays*, H. A. McLaughlin and E. O. Erickson, Westinghouse Elec. and Mfg. Co.
10. *Automatic Switching of Incoming Lines and Transformers Supplying Power to A-C. Sub-Stations*, A. E. Anderson, General Electric Co.
11. *Quantitative Mechanical Analysis for Power-System Transient Disturbances*, R. C. Bergvall and P. H. Robinson, Westinghouse Elec. and Mfg. Co.
12. *Vibration of Transmission-Line Conductors*, Theodore Varney, Aluminum Company of America.

FRIDAY, 12:15 P. M.

Luncheon, Coronado Hotel.

FRIDAY AFTERNOON

Technical Session 9:15 p. m.

SESSION ON COMMUNICATION

B. D. HULL, Presiding

13. *Vector Calculating Devices*, M. P. Weinbach, University of Missouri.
14. *Planning Telephone Exchange Plants*, W. B. Stephenson, Southwestern Bell Telephone Co.
15. *Tuned Radio-Frequency Amplifiers*, Professor R. S. Glasgow, Washington University.
16. Lecture on *Television*, H. E. Ives, Bell Telephone Laboratories.

Regional Meetings at Baltimore and New Haven

Two coming Regional Meetings of the Institute which promise to be of great interest are those to be held at Baltimore, Maryland, April 17-19, and New Haven, Connecticut, May 9-11, respectively.

For the Baltimore Meeting three technical sessions are planned on the subject of insulation, the Gould Street Station of the Consolidated Gas and Electric Company and the Conowingo development of the Philadelphia Electric Company.

At the New Haven Meeting an important subject on the technical program will be the application of relays and the instruments and methods used in determining proper application.

Further details on these meetings will be published in later issues of the JOURNAL.

Tour Through Yellowstone Park Proposed to Follow Summer Convention

A most enjoyable tour has been proposed for Institute members and guests to follow the Summer Convention of the Institute in Denver, June 25-29. The Yellowstone National Park, with its many scenic wonders, willbe the main objective of this trip but other attractive places will be included. The tour will be so planned that members will have to make no train, hotel nor sightseeing arrangements. About three weeks will be required for the tour by members from the East, inclusive of time spent at the convention.

It is believed that many Institute members will take advantage of this unusual opportunity to visit without the burden of detail, and in the congenial company of fellow members, some of the most wonderful sights of this country.

In order that some idea may be obtained of the possible number who would attend, everyone who might be interested in such a tour is requested to communicate with A. I. E. E. headquarters. Further information will be sent to those who are interested.

SUMMER CONVENTION PROGRAM

An exceptional program is being planned for the Summer Convention. Although no definite arrangement is possible at this early date the present plans indicate that there will be technical papers on electrical transportation, communication, operation of electrical equipment at high altitudes, electrical measurements of non-electrical quantities and other timely subjects. The latest developments in all lines of electricity

will be recorded in the annual reports of the Institute Technical Committees which will be presented. The local committee also promises some fine entertainment for the visitors. More complete information will be published in later issues of the JOURNAL.

Midwest Power Conference in Chicago February 14-17

The third annual Midwest Power Conference will be held with headquarters at the Hotel Stevens, Chicago, Illinois, on February 14-17. An excellent program is planned with a number of outstanding speakers. All sessions will be open to interested engineers. An outline of the program is published below and further information may be obtained from G. E. Pfisterer, Secretary, Midwest Power Conference, 930 Monadnock Building, Chicago:

TUESDAY, FEB. 14

8:30 a. m. Registration.
10:30 a. m. Session.
Address of Welcome, Sewell Avery, Pres. Commercial Club of Chicago.
Address by Major Rufus W. Putnam, Chairman of Power Conference.
11:00 a. m. Address. *Power, the Background of Today's Civilization*, Speaker: Glenn Frank, Pres. Univ. of Wis.
2:00 p. m. General Session. "Powers Accomplishments in Factory and Home."
America's Part in the Romance of Power, W. A. Durgin, Dir. Pub. Relations, Com. Edison Co.
Drudgery Banished from the Home, Mrs. J. D. Sherman, Pres. Gen'l Federation of Womens Club.
How to Make the Burden Bearer Bear the Burden, Burke Corcoran, Secy. Elec. Assn. of Chicago.

WEDNESDAY, FEB. 15

9:30 a. m. General Subject: "The Relation of Power Development to Flood Control and Other River Problems."
The General Flood-Control Problems on the Mississippi System, Gen. Edgar Jadwin, Wash., D. C.
Problems of Storage for Flood Control and for Power Development, D. W. Mead, Madison, Wis.
Irrigation and Power-Development Problems on the Colorado River, Col. Kelly, Buffalo, N. Y.
2:00 p. m. *The Tennessee River Survey*, Maj. L. H. Watkins.
Navigation and Power Development on the St. Lawrence River, E. A. Forward, Cons. Engr., Montreal, Can.
The Combined Use of Water and Steam Power, F. A. Allner, Genl. Supt. Penna. Water & Power Co.
Progress and Trend in Hydraulic Power Developments, H. A. Hageman, Chief Hydraulic Engr., Stone & Webster.
7:00 p. m. Annual Banquet, Hotel Stevens.

THURSDAY, FEB. 16

9:45 a. m. Session: "Economics of Power Stations."
Capital Costs with Relation to Economy of Central Stations, Alex Dow, Pres. Detroit Edison Co.
High Pressure Operation, G. A. Orrok, Con. Engr., N. Y. City.
Trend and Development in Steam Generation, Thos. E. Murray of Thomas E. Murray, Inc.
1:00 p. m. Luncheon Symposium.
Underground Transmission Developments and the General Effect Upon Reliability of Service, H. B. Gear, Commonwealth Edison Co.
Overhead Transmissions, Geo. F. Humphrey, West Penna. Power Co.
Equipment for Power Transmission, A. C. Monteith, Westinghouse Elec. & Mfg. Co.
2:00 p. m. Inspection trips.

FRIDAY, FEB. 17

9:45 a. m. Session: Economics of Power Stations. (Fuel, Combustion, etc.)
Combustion Control in Industrial Plants, T. A. Peebles, Hagan Corp.
Combustion Control in Central Stations, Chas. H. Smoot, Smoot Engr. Co.
The Effect of Steam Reheating, Stage Feed Water Heating, and Boiler Reheating on Steam Turbine Practise and Development, Edward Brown, Allis-Chalmers Co.
Embrittlement of Boiler Plate, S. W. Parr and F. C. Straub, U. of Ill.

Revised Section No. 7 A. I. E. E. Standards Now Available

A new and considerably revised edition of Section No. 7, A. I. E. E. Standards for Alternators, Synchronous Motors and Synchronous Machines in General, has just become available. This new edition embodies the changes made by the Section Committee on Rating of Electrical Machinery and also includes the work of the Sectional Committee on Alternators, Synchronous Motors, etc. This latter committee, organized as was the Rating Committee under the auspices of American Engineering Standards Committee, has been engaged in the work of revision of the first edition of the Alternator Standards with the purpose of eventually recommending them to American Engineering Standards Committee for adoption as American Standard.

The principle changes involved in this revision deal with the rating of general purpose motors and the calculation of natural frequency of synchronous machines. The cast of the new edition has not been changed. It is 40 cents with a 50 per cent discount to A. I. E. E. members. Those interested in this or other Standards should communicate with the Secretary of Standards Committee, A. I. E. E. headquarters and request the "Index of Standards" which gives scope of each section, prices, and list of reports on future Standards.

AMERICAN ENGINEERING COUNCIL

THE ANNUAL MEETING, WASHINGTON, D. C.

The Annual Meeting of the American Engineering Council was held in Washington, D. C., at the Mayflower Hotel, January 9-11, 1928. The various national, state and regional engineering societies, constituting the membership of the Council, were practically all officially represented, attendance of delegates and others interested being approximately one hundred. President Dexter S. Kimball, of Cornell University, presided.

The following constitutes a brief summary of the more important actions taken:

Appointment was announced of a Flood Control Committee to work with Congress and to study the whole national situation with a view to preventing disasters such as have occurred along the Mississippi and in New England.

G. S. Williams is chairman. Other members are: Baxter L. Brown, St. Louis; John R. Freeman, Providence, R. I.; past.

president of the American Society of Civil Engineers; Arthur E. Morgan, president of Antioch College, Yellow Springs, Ohio. A fifth member is to be appointed.

The Committee will study the reports of the Engineer Corps and the Mississippi River Commission, and thoroughly familiarize itself with the problem so that it may be prepared to recommend appropriate action by the organized engineering profession of the United States.

The Committee was instructed to cooperate with the Flood Control Committee of the House of Representatives, and to present the attitude of the American Engineering Council at Congressional hearings and elsewhere.

Opposition to the expenditure of public moneys for the Boulder Dam project, for the aid of commercial aviation, and for the development of agriculture, home economics and industry, was voiced in resolutions passed by the Council.

Acting upon the recommendations of its Public Affairs Committee, the Council voted its disapproval of the Swing-Johnson Bill, which provides for the construction of works, for the protection and development of the Lower Colorado River Basin, and for the approval of the Colorado River Compact.

The engineers objected to that provision of the Bill which establishes the "Colorado River Dam Fund" to receive advances from the Government not exceeding $125,000,000 on the ground that it involves Federal ownership and the sale of power.

The Council opposed the Bill introduced in the House by Representative McLeod, providing governmental aid in commercializing aviation in the United States, its territories, and possessions, because "it is contrary to the recommendations contained in the report on Civil Aviation prepared by American Engineering Council and the Department of Commerce."

The Bill of Senator McKellar to establish the Muscle Shoals Commission was also condemned by the engineers. Among those who spoke in opposition to this measure was Dr. Harrison E. Howe, editor of "Industrial and Engineering Chemistry," and a member of the National Research Council.

Discussion of the Bill of Representative Tillman brought out the unanimous opinion that the engineering profession should support a sound Federal program to assist agriculture, but that this Bill, which makes annual advances by the Government to develop agriculture, home economics and industry, does not coincide with the engineering point of view.

At the end of eleven years, the yearly appropriations for these purposes, according to the provisions of the Tillman Bill, would aggregate $6,000,000. Further investigation of the whole problem was urged by the engineers.

The Council voted to support the Bill of Senator Ransdell which would place the proposed National Hydraulic Laboratory in the Bureau of Standards. Other bills now pending in Congress would assign the Laboratory to the Engineers Corps and to the Mississippi River Commission.

The Council favored in principle that section of the House Bill which provides for the establishment in the Department of Labor of a Bureau of Labor Statistics, but refused to endorse the provision for the creation of a Safety Museum.

It was also voted to oppose the passage of the House Bill which prevents the use of stop watches or time measure devices, and to support the House Bill establishing requirements affecting Government contracts.

The engineers discussed the House measure which would create a commission to ascertain the feasibility of constructing the Nicaraguan Canal, and finally referred the question to the American Society of Civil Engineers with a request for recommendations thereon.

The Council adopted the report of its Committee on Street Signs, Signals and Markings, which has just completed a nationwide survey of traffic conditions in more than one hundred cities with a population exceeding 35,000,000.

The Committee, it was declared, has successfully accomplished "the most comprehensive study yet made of traffic control devices." Headed by W. B. Powell of Buffalo, N. Y., it enlisted the cooperation of more than 500 engineers, who reported vast discrepancies in the signs, signals and markings used throughout the country with little regard for standardization.

The Committee, according to the Council's announcement, has set up a recommended standard set of signs and established specific recommendations for the maintenance, color, material, location and method of illuminating these signs.

As to signals, the report, it was said, points the way to simple standards for universal use. Other recommendations of the report "are aimed to aid cities in getting that type of traffic control best suited to their needs." A system of pavement and curb markings leading to simplicity and uniformity is also recommended.

Officers Elected

The officers elected for the coming year were—President; Arthur W. Berresford, of New York, a past-president of the American Institute of Electrical Engineers; Vice-Presidents: I. E. Moultrop, of Boston; Gardner S. Williams, of Ann Arbor, Michigan; O. H. Koch, of Dallas, Texas; and L. P. Alford, of New York; Treasurer: Harrison E. Howe, re-elected; Executive-Secretary: L. W. Wallace, re-elected.

The representatives of the A. I. E. E. present were—A. W. Berresford, New York; John H. Finney, Washington, D. C.; M. M. Fowler, Chicago; H. M. Hobart, Schenectady; F. L. Hutchinson, New York; H. A. Kidder, New York; I. E. Moultrop, Boston; Farley Osgood, New York; Charles F. Scott, New Haven; C. E. Skinner, Pittsburgh; and Calvert Townley, New York.

The delegation selected to represent the A. I. E. E. upon the Administrative Board of the Council (in addition to President Berresford and Vice-President Moultrop), is composed of John H. Finney, M. M. Fowler, H. A. Kidder, Farley Osgood, Charles F. Scott, and C. E. Skinner.

Kansas City Engineers Club Extends Welcome

The Engineers Club of Kansas City extends a cordial invitation to all Institute members who may be in Kansas City at any time to visit the Club. A meeting with some form of program or entertainment is held in the Roof Garden of the Aladdin Hotel every Monday noon. The Kansas City Section of the Institute and other local organizations are affiliated with the Engineers' Club.

Welding Meeting Held in Boston

A joint meeting on welding was held December 14, 1927 under the auspices of the Affiliated Technical Societies of Boston (Mass.), of which the Boston Section of the Institute is a member. Three sessions were held—morning, afternoon and evening,—at which the following 12 papers were presented:

General Principles of the Various Welding Processes, by F. M. Farmer, Chief Engr., Electrical Testing Laboratories;

Examples of Arc-Welded Steel Construction, by G. D. Fish, Consulting Engr., Westinghouse Electric & Mfg. Co.;

Welding Trusses for Industrial Buildings, by Andrew Vogel, General Electric Co.;

Pipe Line Welding from the Oxy-Acetylene Viewpoint, by LeRoy Edwards, Air Reduction Sales Co.;

Pipe Welding and Other Recent Developments in Welding, by D. H. Deyoe, General Electric Co.;

Thermit Pipe Welding, by R. L. Browne, Metal & Thermit Corp.;

Replacing Castings by Steel Elements Cut to Shape by Automatic Shape-Cutting Machines, by Dr. A. Krebs, General Welding and Equipment Co.;

The Metallurgy of Welding-Wire, by C. A. McCune, American Chain Co.;

Unit Stresses and Reliability as Applied to Structural Welding, by F. T. Llewellyn, Representative of A. S. C. E. on Joint Structural Welding Committee;

Applications of Projection and Multiple Welds, by W. T. Ober, Thomson Electric Welding Co.;

Reclaiming a Cast-Iron Waterwheel Casing, by C. W. Babcock, Westinghouse Electric & Mfg. Co.;

Atomic-Hydrogen Welding Process, by P. Alexander, General Electric Co.

The annual Engineers Banquet was held in conjunction with the meeting.

PERSONAL MENTION

R. B. Ransom has been appointed resident agent in charge of the Hartford office of the General Electric Co., succeeding Mr. Gregory.

B. L. Delack (Assoc.), has been appointed manager of the Schenectady plant of the General Electric Company as of January 1, 1928.

E. A. Wagner (Assoc.), has been appointed manager of the Pittsfield, Mass., plant of the General Electric Company, effective January 1, 1928.

C. N. Gregory (Assoc.), as manager of the New Haven, Conn., office succeeds Frederic Cutts (Mem.) in the sales organization of the General Electric Co.

Thomas Ahearn, who is an outstanding figure in the activities of Ottawa, Canada, has just had the new honor conferred upon him of appointment to the Privy Council.

R. M. Eaton on January 1, 1928, changed his position from superintendent of the Okonite-Callender Cable Company to superintendent and resident manager of the Hazard Manufacturing Company Division of the Okonite Company.

Walter H. Smith has resigned from his position as Railway Equipment with the Westinghouse Electric & Mfg. Company to join the engineering staff of the Reading Company in connection with the electrification of the Reading Terminal at Philadelphia.

A. H. Manwaring, who has served the Philadelphia Electric Company for some time, of late in the capacity of Engineer of Transmission and Distribution has retired from active service and will reside at Jenkintown, Pa. Mr. Manwaring joined the Institute in 1909.

H. F. T. Erben (Assoc.), assistant vice president of the General Electric Company, retired on January 1, 1928, after more than 40 years of service with that company. At the time of his retirement he was also vice chairman of the General Electric Co's manufacturing Committee.

W. J. Canada, formerly Electrical Field Secretary for the National Fire Protection Association has just received appointment as a staff officer of the National Electrical Manufacturer's Association and all engineering matters affecting the entire membership will hereafter be correlated and directed by him.

Obituary

Ralph M. Obergfell, Associate Electrical Engineer of Underwriters Laboratories and a member of the Institute since 1912, died January 10, 1928, of pneumonia. He was born in Chicago, February 8, 1888, and received his technical education at Lewis Institute from which he graduated in 1911. Entering the employ of the Sanitary District of Chicago he was soon promoted to the position of assistant power house operator; in fact it was remarked that he was "always in line for further advancement." From childhood his record was one of sterling character.

Harry Edgar Hayes, member of the Institute since 1893 and of late with Charles H. Tenney & Company, Boston, Mass., died at his home, Stoneham, Mass., December 2, 1927, from the result of a throat infection.

Mr. Hayes was born at Madbury, N. H., December 12, 1865. When he was two years old the family removed to Boston, and Mr. Hayes was graduated from the Latin School there. He later attended Harvard College, graduating with the class of '88 and Massachusetts Institute of Technology, with the class of '90. He returned to M. I. T. for a year as Assistant in Mechanical Engineering and later became Assistant Electrician of the American Telephone and Telegraph Company, remaining in that capacity until 1907. In 1909 he took up the design and erection of buildings and study of plant layout for the Laconia Car Co., with which he was occupied until 1914. The following year he joined the force of the Electrical Testing Laboratory but in 1916 returned to the New England Section to take up the underground work for the Salem Electric Light Company, Salem, Mass. With the Tenney & Company, Mr. Hayes service was as inspector of underground construction for Light and Power.

Allen H. Moore, General Engineer of the General Electric Company, Schenectady and for some time the chairman of its Standardizing Committee, died Tuesday, January 10, at Albany, New York, after a brief illness. He was born at Rutland, Vermont, and his general education was public and high school followed by a 2-years' academic course at the University of Vermont at Burlington and two years at Rose Polytechnic Institute, where he took up electrical engineering. This he followed by student work in the factory of the Thomson-Houston Electric Company, Lynn, Massachusetts, upon the installation of lighting plants and later becoming "trouble man." He was then sent to Washington and later to the Pittsburgh offices. His work included the installation of plants in Canada and Mexico. He was also given charge of the Thomson-Houston Company's exhibit at the Frankfort Exposition, Germany, after which he became chief engineer and manager of the factory of the Union Elektricitaets Gesellschaft, a company originally formed by the General Electric Company and German interests. Mr. Moore was put in responsible charge of the designing and manufacturing for the company, which built a-c. and d-c. generators and motors of all kinds, as well as railway equipment and heavy electrical apparatus. The greater portion of the more intricate and important part of this design work was done by Mr. Moore, personally. In 1899 he went to London as general manager of works for the British Thomson-Houston Co., and in this capacity built and equipped the company's Rugby works. In 1901, however, he returned to the Engineering Executive Department of the General Electric Company, as assistant to Mr. E. W. Rice and chairman of the Standardizing Committees, which brought him in intimate contact with all the design engineering of the General Electric Company. He was a man of wide experience and of high worth.

Elmer Ellsworth Farmer Creighton, an electrical engineer of the General Electric Company, and for years the Company's expert on lightning protection, died January 12 at Ellis Hospital, Schenectady, after a prolonged illness. He had been identified with the General Electric Company in this city since 1904 and was for a long period a close technical associate of the late Dr. Charles Proteus Steinmetz.

Mr. Creighton was born April 11, 1873, at Vallejo, California. He was graduated in 1895 from Leland Stanford University with the B. S. degree and received from the same institution the degree of electrical engineer in 1897. He was special testing engineer for the Pacific Postal Telegraph Company at San Francisco from 1894 to 1895, and had served in 1895-6 as instructor at Leland Stanford University. In the summer of 1897 he served as assistant to Dr. David Starr Jordan on the fur seal commission in the Pribilof Islands, Alaska. From 1898 to 1900 he was at the Sorbonne in Paris and was connected with the

Ecole Superieure d'Electricite as assistant to M. Andre Blondel in special research work.

After his return from Paris in 1900, Mr. Creighton again taught for a brief period at Leland Stanford but in 1901 he came east and took a position as head of the experimental department of the Stanley Electric Manufacturing Company at Pittsfield. He was engaged thus until in 1904 the Stanley Company became part of the General Electric Company whereupon Professor Creighton came to Schenectady and was associated for the first time with Dr. Steinmetz who was then head of the electrical engineering department at Union College. From 1904 to 1906 he was assistant to Dr. Steinmetz in this department and it was during this interval that an experimental laboratory, conducted by these two and others of the college faculty, but designed to serve the needs of the General Electric Company, was established in Washburn Hall, Union College. Much pioneer work in the study of protective devices and methods for transmission systems was done in this laboratory. The researches continued at Union College until the fall of 1913, when the laboratory was moved to the Schenectady plant of the General Electric Company where it has since remained. It was at that time placed under the consulting engineering department of which Dr. Steinmetz was the head, and some years later it was consolidated with the Standardizing Laboratory to form the present General Engineering Laboratory, in which department Professor Creighton was serving at the time of his death.

During the nearly quarter century stretch from 1904 Professor Creighton had performed a great deal of high tension and lightning protection investigation. He had been an inventor of many protective devices for electrical systems including an aluminum lightning arrester, direct-current and alternating-current arresters, a compression chamber arrester, a dry-film arrester and concrete reactors, as well as other less important devices.

Professor Creighton served on many technical committees of the Institute, specifically the Meetings and Papers Committee and committees relating to protection; also on the American Engineering Standards Committee. He was a Fellow and member of the Society for the Promotion of Engineering Education, the American Association for the Advancement of Science, the American Society of Mechanical Engineers, the American Physical Society, the American Electro-Chemical Society, the American Ceramic Society, the Société Francaise des Electriciens, a Fellow of the Institute and Sigma Xi.

Professor Cerighton had written many technical papers and was a frequent lecturer at colleges and before technical audiences. He held a number of medals.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Anyone knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute Headquarters promptly of any changes in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

Wm. S. Barden, 514 Todd St., Wilkinsburg, Pa.
H. S. Bedi, c/o Y. M. C. A., Elizabeth, N. J.
A. B. Blatherwick, P. O. Box 857, Bremerton, Wash.
David E. Carpenter, 136 Woodland St., Worcester, Mass.
John F. Dreyer, Jr., Stevens Inst. of Tech., Hoboken, N. J.
J. B. Entz, Beechmont Drive, New Rochelle, N. Y.
Jos. E. Gartenman, Box 19, Eastside P. O., Providence, R. I.
Geo. B. Germain, Westinghouse E. & M. Co., Chicago, Ill.
King E. Gould, 3 William St., Cambridge, Mass.
Joel Hakanson, 1935 Daly Ave., New York, N. Y.
Ralph E. Ingersoll, 1110 Wood St., Wilkinsburg, Pa.
George T. Lawson, 1644 43rd St., Brooklyn, N. Y.
Joseph M. Lyden, Finkbine Guild Lbr. Co., Rockport, Calif.
Samuel Parmley, P. O. Box 256, Gary, Ind.
E. B. Schultz, 2024 Locust St., Long Beach, Calif.
James P. Scott, 503 W. Michigan Ave., Jackson, Mich.
S. D. Thordarson, 115½ East Ave. 36, Los Angeles, Calif.
Wm. M. Van Sant, 531 Elm St., Reading, Pa.
Leo J. Vonsovich, 1730 Hearst Ave., Berkeley, Calif.
R. M. Wild, c/o Stone & Webster, Inc., Boston, Mass.
Ralph Wilder, 1144 W. 51st St., Los Angeles, Calif.

A. I. E. E. Section Activities

FUTURE SECTION MEETINGS

Cleveland

Power Plant Development, by C. F. Hirshfeld, Detroit Edison Co. Electric League Room, Hotel Statler, 8:00 p. m. February 16.

Joint meeting with Case School of Applied Science Branch. March 22.

Columbus

Modern Trend in Large Generating Apparatus, by F. D. Newbury, Westinghouse Electric & Mfg. Co. Film, entitled "From Coal to Electricity." February 24.

Joint dinner meeting with Engineers' Club of Columbus. March 23.

Detroit-Ann Arbor

"Electricity in Modern Office Buildings," by George Wagschal, Consulting Electrical Engineer. February 21.

Erie

Commercial Aviation, by W. B. Stout, Stout Metal Airplane Co. February 21.

Tendencies in Modern Transportation, by N. W. Storer, Westinghouse Electric & Mfg. Co. March 20.

Lynn

Hydroelectric Development and Interconnection in the Southern States, by W. E. Mitchell, Vice-President, Georgia Power Co. 42 Centre Street, West Lynn. February 13.

Local convention, with papers by members of the Thomson Research Laboratory, G. E. Co. 42 Centre Street. February 29.

The Grand Canyon, Southeastern Utah, the Zion and Bryce Canyons, by Randall Jones. Ladies' Night. First M. E. Church, City Hall Square. March 7.

Niagara Frontier

Latest Developments of Welding, by C. L. Ipsen, General Electric Co. February 10.

Automatic Control of Substations by Means of Supervisory Control and Other Methods, by R. J. Wensley, Westinghouse Electric & Mfg. Co. March 2.

Pittsburgh

The Engineer in Industry, by W. S. Rugg, Vice-President, Westinghouse Electric & Mfg. Co. February 14.

Vacuum-Tube Applications, by T. A. E. Belt, General Electric Co. March 13.

Pittsfield

Floods and Flood Control, by Dr. Frank Bohn. Masonic Temple. February 7.

Heaviside's Operational Calculus, by Dr. E. J. Berg, Union University. Stanley Club Rooms. February 21.

Conditions in China, by Dr. Tehyi Hsieh. Masonic Temple. March 6.

St. Louis

Superpower Transmission, by Robert Treat, General Electric Co. February 15.

Television, by Dr. H. E. Ives, Bell Telephone Laboratories. March 21.

Sharon

New Developments in Supervisory Control, by R. J. Wensley, Westinghouse Electric & Mfg. Co. Moving pictures and demonstration. February 7.

Elements of Vector Analysis for the Mechanical and Electrical Engineer, by Prof. V. Karapetoff, Cornell University. Lecture at 4:00 p. m.—Piano Recital at 8:00 p. m. February 25.

Meeting in Y. M. C. A. Auditorium, Youngstown, O. Addresses and lantern slides. Inspection of 132-kv. substation. Transportation in P. & O. busses. March 6.

Vancouver

Students' Night at University of British Columbia. February 7.

Impressions of a Recent Visit to Europe, by F. J. Bartholomew of Bartholomew, Montgomery & Co., Ltd. March 6.

SECTION MEETINGS

Atlanta

Annual Dinner. The following officers were elected: Chairman, T. H. Landgraf; Vice-Chairman, W. F. Oliver; Secretary-Treasurer, S. C. Bleckley. September 30. Attendance 25.

Business Meeting. Daniel H. Woodward was elected Secretary-Treasurer to succeed S. C. Bleckley. A luncheon preceded the meeting. November 25. Attendance 18.

Boston

All-day Meeting on Welding. (See details elsewhere in this issue). December 14.

Television, by J. W. Horton, Bell Telephone Laboratories. Accompanied by moving pictures. January 11. Attendance 460.

Cleveland

Television, by J. W. Horton, Bell Telephone Laboratories. Illustrated by slides and moving pictures. December 15. Attendance 131.

Columbus

Manufacture of Carbon Brushes from Raw Materials, by W. C. Kalb, National Carbon Co.;

Sound Control of Substations, by A. E. Williams, Columbus Section, and

Radio Development, by Prof. A. F. Puchstein, Ohio State University. Motion picture, entitled "Behind the Pyramids," was shown. December 2. Attendance 25.

Denver

The Problems of a Broadcasting Manager, by F. H. Talbot, Manager, KOA. December 15. Attendance 112.

Erie

The Romantic Development and Economics of Niagara Power, by W. K. Bradbury, Niagara Falls Power Co. Illustrated with slides. December 20. Attendance 40.

Fort Wayne

Television, by H. M. Stoller, Bell Telephone Laboratories. Illustrated with slides and motion pictures. December 15. Attendance 185.

Kansas City

Power-System Stability, by A. D. Dobjikob, Westinghouse Electric & Mfg. Co. December 5. Attendance 52.

Los Angeles

Vacuum Tubes in the Electrical Industry, by L. F. Fuller, General Electric Co. Illustrated with slides. A dinner preceded the meeting, at which Dr. Harold Norinder, Royal Board of Water Falls, Stockholm, Sweden, spoke on "Lightning and High-Voltage Surges on Transmission Lines." January 6. Attendance 126.

Louisville

An Engineering Paradox, by Dean P. S. Anderson, University of Kentucky. Joint meeting with A. S. M. E. November 22. Attendance 63.

Recent Developments in the Bell Laboratories, by L. S. O'Roark, Information Manager. Illustrated. Joint meeting with A. S. M. E. and Engineers and Architects Club. December 20. Attendance 115.

Lynn

Trends in Central Station Development, by G. A. Orrok, New York Edison Co. Illustrated with slides. December 14. Attendance 120.

Age of Speed, by R. P. Capron, Norton Grinding Co. Illustrated with motion picture. January 11. Attendance 175.

Mexico

The Hydraulic Side of the Tepuxtepec Hydro-Electric Development, by G. Gibellini, Mexican Light & Power Co. December 6. Attendance 51.

Milwaukee

Engineering Principles Applied to Finances, by R. M. Laas, Morris F. Fox & Co. December 21. Attendance 75.

Minnesota

Engineers and Municipal Government, by A. C. Godward, City Planning Engineer, Minneapolis. January 3. Attendance 20.

New York

Interconnection of Power Systems. (See details elsewhere in this issue.) January 13. Attendance 750.

Philadelphia

Transmission of Pictures, by W. E. Harkness, A. T. & T. Co. Illustrated with slides. A dinner preceded the meeting. December 12. Attendance 210.

Pittsburgh

Engineers Versus Salesmen—Who's Ahead? by G. M. Gadsby, President, West Penn Power Co. Joint meeting with Engineers Society of Western Pennsylvania. Motion pictures. December 13. Attendance 250.

Pittsfield

Hot Cathode Power Rectifiers, by A. W. Hull, General Electric Co. Illustrated with slides. December 20. Attendance 75.

Portland

Flood Conditions in the Mississippi Valley, by Lieut. Col. G. R. Lukesh. Illustrated with slides. Joint meeting of Portland Engineering Societies. December 13. Attendance 150.

Rochester

Additions and Betterments to the Rochester Gas and Electric Corporation's System, by E. K. Huntington, L. R. Scott, and C. A. Woodruff. Illustrated by slides. December 16. Attendance 87.

St. Louis

Railway Electrification, by J. V. B. Duer, Pennsylvania Railroad System. Illustrated with slides. December 22. Attendance 43.

San Francisco

Choice of Power Supply for Central Station Industry, by A. H. Markwart. August 25. Attendance 125.

Talk by Bancroft Gherardi, National President, A. I. E. E. September 1. Attendance 50.

Recent Discoveries and Developments in the Art of Power Transmission, by R. D. Evans, Westinghouse Electric & Mfg. Co. A dinner preceded the meeting. Setpember 23. Attendance 65.

Celebration of "First Centenary of Alessandro Volta. Joint meeting with Italy-America Society of San Francisco. November 4. Attendance 45.

Inspection trip to Oakland Lamp Factory of the General Electric Company. December 9. Attendance 105.

Schenectady

Theory of Light Production in Gases, by Dr. S. Dushman, General Electric Co. and *Hot-Cathode Neon Arcs*, by C. G. Found, General Electric Co. Slides and demonstration. December 16. Attendance 100.

Seattle

Design and Construction of the Chelan Plant, Dam and Tunnel, by V. H. Greisser, Washington Water Power Co. Illustrated. A dinner preceded the meeting. December 20. Attendance 119.

Sharon

New and Interesting Electrical Developments, by A. M. Dudley, Westinghouse Elec. & Mfg. Co. Talk by Larry Flint, newspaper man. A banquet preceded the meeting. December 6. Attendance 196.

Spokane

The Spokane A-C. Underground System, by Earl Baughn, Washington Water Power Co. December 20. Attendance 32.

Springfield

Film, entitled "From Coal to Electricity," was presented by A. A. Northrup, Consulting Engineer, Stone & Webster Co. The speaker also described by means of slides and motion pictures the hydro-electric development at Conowingo, Maryland. Joint meeting with Engineering Society of Western Massachusetts. December 13. Attendance 134.

Toledo

Theory and Practise in Transformer Operation for Modern Interconnected Transmission Network, by W. A. Furst, Westinghouse Electric & Mfg. Co. December 16. Attendance 50.

Washington

Research and Invention, by S. M. Kintner, Westinghouse Electric & Mfg. Co. December 13. Attendance 105.

Safety in Power-Plant Construction, by C. R. Beardsley, Brooklyn Edison Co. Illustrated with slides. January 10. Attendance 165.

Worcester

The New Aircraft Carrier, by Commander Theodore G. Ellyson, U. S. S. *Lexington*. Joint meeting with other engineering societies. December 19. Attendance 175.

A. I. E. E. Student Activities

Large A. I. E. E. Student Conference at Pittsburgh

On January 10, 1928, one of the largest Student Branch conferences ever held in Pittsburgh brought together students from West Virginia University, Carnegie Institute of Technology and the University of Pittsburgh, to honor Mr. Bancroft Gherardi, President of the American Institute of Electrical Engineers. This student conference was beyond doubt a most successful and inspiring meeting. The afternoon was filled with events of interest to the students, including inspection trips through the laboratories of the Carnegie Institute of Technology and the University of Pittsburgh, and luncheon at Carnegie Library Cafeteria. This was followed by an afternoon program in the Fellows Room of the Mellon Institute of the University of Pittsburgh. The program was filled with good talks and discussion by the students. The following papers were presented:

The Value of Good English to an Engineer, W. E. Vellines, West Virginia University.

An Incident in Electrical Engineering, R. R. Lockwood, Carnegie Institute of Technology.

Hydroelectric Possibilities of South America, R. Vecino, University of Pittsburgh.

The Engineer as a Citizen, S. C. Hill, West Virginia University.

Antenna Radiating Systems for Short Waves, R. S. Tener, Carnegie Institute of Technology.

An Experience in Obtaining and Marketing a Patent, C. Cavery, University of Pittsburgh.

How Shall We Stimulate the Interest and Enthusiasm of the Students in the Student Branch? C. L. Parks, West Virginia Unversity. Discussion was led by R. A. Ramson, Carnegie Institute of Technology, and K. A. Wing, University of Pittsburgh.

How Can the Journal be Made of Greatest Value to the Student?, John E. White, Carnegie Institute of Technology.

What Part Should the Faculty Take in Branch Activities?, R. P. Synder, University of Pittsburgh.

At this time the chairman introduced Mr. F. J. Chesterman, Vice President and General Manager of the Bell Telephone Company of Pennsylvania. After a brief address Mr. Chesterman presented Mr. Charlesworth, Chairman of the Meetings and Papers Committee, who gave a short address on the value of such a conference to the future electrical engineer. Mr. Bancroft Gherardi, President of American Institute of Electrical Engineers, and Vice-President of the American Telephone and Telegraph Company, was then introduced by Mr. Chesterman, and spoke on the various phases of individual development necessary for success. The students considered it quite an honor to have President Gherardi as their guest and to listen to his address.

The conference was attended by 80 students. Of that number, 40 students attended the dinner and meeting of the Pittsburgh Section of the A. I. E. E. and the Electrical Section of the Engineers Society of Western Pennsylvania held that evening in the Chamber of Commerce Building in honor of President Gherardi. In connection with the evening meeting, Mr. G. B. Pyles, Chairman of the Student Branch, West Virginia University, gave a report of the Student Conference held that afternoon.

The other parts of the evening program were:

Illustrated address on *Trans-Altantic Radio*, by President Gherardi.

Symposium on *A-C. Network Systems:*

Engineering Aspects, by C. T. Sinclair, Assistant Electrical Engineer, Byllesby Engineering and Management Corporation, Pittsburgh Branch.

Operating Performance, by H. R. Searing, Assistant Electrical Engineer, United Electric Light and Power Company, New York City.

BRANCH MEETINGS

University of Arkansas

Audio Amplification, by Prof. Loy Barton. December 14. Attendance 36.

Armour Institute of Technology

Joint meeting with A. S. M. E. November 18. Attendance 30.

Standardization under Hoover, by W. A. Durgin. December 16. Attendance 30.

California Institute of Technology

Commercial Electric Motors, by H. C. Hill, General Electric Co. Motion pictures, entitled "The Conductor," and "The Busy Body," were shown. December 9. Attendance 18.

Carnegie Institute of Technology

Televox, by Robert Lockwood, student. December 7. Attendance 35.

Case School of Applied Science

Experiences with the Ohio Public Service Company, by S. E. Abell

and W. E. Hoehn, students. The meeting was preceded by a dinner. December 6. Attendance 28.

Clemson Agricultural College

Ventilation of the Holland Tunnel, by R. N. Anderson;

Lightning Prevention, by J. F. Callaham;

The Giant of Broadcasting, by B. H. Cuttino, and

Current Events, by W. H. Cuttino. December 1. Attendance 26.

Panel Material for Switchboards, by F. F. Tice;

Electrical Reproduction of Phonograph Records, by J. H. Clark;

Televox, by G. P. Cobb, and

Current Events, by A. P. Wylie. December 15. Attendance 24.

University of Colorado

Long Distance Telephone Transmission, by E. Hattrick, Transmission and Protection Engineer for Colorado, Mountain States Telephone Co. The paper was prepared by R. B. Bonney, Educational Director of that company. January 4. Attendance 45.

University of Denver

Some Recent Work on Lightning Discharge, by J. N. Petrie. Motion pictures, entitled "The Moulder," and "Liquid Air," were shown. December 16. Attendance 43.

University of Florida

Radio Broadcasting, by A. M. Skellet, Instructor in Electrical Engineering. October 31. Attendance 25.

Motion picture, entitled "The Making of Armco Ingot Iron," was shown. November 14. Attendance 35.

The Mercury Vapor Process of Power Generation, by A. C. Dean, Secretary of the Branch. November 28. Attendance 20.

Georgia School of Technology

First Aid, by Jack Milan, First Aid Instructor for the Georgia Power Co. The speaker demonstrated the Schaefer method of artificial respiration. January 6. Attendance 53.

Kansas State Agricultural College

The Electronic Rectifier, by W. L. Garnett, student, and

Electrical Current Events, by F. B. Volkel, student. Two films were shown—one of the K. S. A. C. and the other entitled "Land of Cotton." December 5. Attendance 86.

Illumination, by Prof. O. D. Hunt;

Electrical Current Events, by W. D. Nyhart, student, and

Technical Talk, by Paul Ayres. Motion picture, entitled "Light of the Race," was shown. December 19. Attendance 96.

University of Kansas

What Electricity Has Done for Mankind, by C. M. Ripley, General Electric Co. Illustrated with motion pictures. Joint meeting with Student Chapter, A. S. M. E. December 13. Attendance 325.

Lafayette College

Motion pictures, entitled "60,000 Kw. Turbine-Generator Set,' "91,500 Kw. Cross-Compound Turbine-Generator Set," "100 Kw. Vacuum Tube," and "Coolidge Cathode Ray Tube." January 7. Attendance 20.

Lehigh University

Electrical Indicating Instruments, by A. F. Corby, Jr., Weston Electrical Instrument Corp. December 9. Attendance 85.

Lewis Institute

Business Meeting. Discussion of Regional Meeting at Chicago and future Branch programs. A. R. Sansone was elected Chairman to succeed L. F. Masonick who resigned. January 10. Attendance 26.

University of Maine

A Summer with Westinghouse Electric & Manufacturing Company, by P. H. Trickey and G. R. Chappell, students. January 4. Attendance 19.

Massachusetts Institute of Technology

Motion pictures, entitled respectively "Revelations by X-Rays," and "Power Transformers, Their Development and Manufacture," were shown. December 7. Attendance 40.

Some Valuable Advice to the Students Regarding Their Future, by E. S. Mansfield, Supt. of the Operating Power Accounting Department of the Edison Electric Illuminating Company of Boston. Motion picture, entitled "More Power to You," was shown. A free supper preceded the talk. December 16. Attendance 250.

University of Michigan

Imaginative Engineering, by Wm. Dreese, Lincoln Motors Co. December 9. Attendance 29.

University of Minnesota

Reserves in Central Station Industry for Maintaining Electrical Service, by H. E. Wulfing, Commonwealth Edison Co. November 15. Attendance 115.

Business Meeting. John Krichbaum appointed Branch Safety Representative. Decided to send C. L. Elliott, a junior, to Regional Meeting in Chicago with expenses paid by the Branch. November 25. Attendance 8.

Mississippi A. & M. College

Life and Work of the Young Graduate in the Testing Laboratories of a Large Manufacturing Corporation, by Prof. Commander. L. H. Calloway, Chairman of the Program Committee announced plans for programs for the Spring semester. December 6. Attendance 28.

University of Nebraska

Dr. E. B. Roberts, Supervisor of Service to Engineering Schools, Westinghouse Electric & Mfg. Co., gave a talk on the choice of positions best adapted to the characteristics of individuals. Talks were also given by Mr. McLaren and Mr. Morgan of the same company on production and sales methods respectively. Dean O. J. Ferguson gave a short talk to stimulate interest in Student enrolment. Prof. F. W. Norris, Couselor, announced that the District Conference on Student Activities will be held in Lincoln this year, probably early in March. November 23. Attendance 89.

University of Nevada

Transformers, by W. C. Smith, Sales Engineer, General Electric Co., San Francisco. Illustrated. December 7. Attendance 41.

Newark College of Engineering

Schaefer Prone Pressure Method of Resuscitation, by Mr. Alexander, Public Service Electric & Gas Co. Motion picture, entitled "Modern Miracle," was shown. December 18. Attendance 32.

University of New Hampshire

Television, by E. L. St. Clair, and

High-Speed Circuit Breakers, by C. E. Turschman. November 16. Attendance 38.

Constant Current Transformers, by G. P. Balch; D. Williams;

Temperature Control by the Pyrometer-Potentiometer Method, by L. Whitten; F. E. Beede, and

Baum Principle of Transmission, by R. B. Wilson; L. E. Boodey. November 23. Attendance 37.

The Development of the Radio Circuit, by P. Zottu; F. Drew; and

Refrigeration, by H. B. Rose; R. W. Folsom. November 30. Attendance 39.

Film, entitled "Nature's Frozen Credits," was shown. January 9. Attendance 39.

College of the City of New York

Inspection trip through the radio receiver factory of the Freed-Eisemann Corporation. December 15. Attendance 9.

Conowingo Hydroelectric Development, by A. A. Northrop, Stone & Webster Co. Illustrated with slides and three reels of motion pictures, entitled "Conowingo." Joint meeting with A. S. C. E. and A. S. M. E. December 22. Attendance 72.

University of Notre Dame

Condensers in Radio Circuits, by G. P. Kennedy, and

Development and Manufacture of Lubricating Oils, by C. G. Kustner, Standard Oil Co. of Indiana. Illustrated with three reels of motion pictures. Refreshments served after the meeting. December 12. Attendance 101.

Ohio University

Problems of the Plant Manager, by Mr. Badger, Plant Manager of the Floodwood Station, South-Eastern Ohio Power Co. December 7. Attendance 25.

Ohio State University

Motion picture on the manufacture of insulators was shown. December 2. Attendance 30.

Television, by R. A. Dellar, Bell Telephone Laboratories, Inc. Prof. F. C. Caldwell, Counselor, gave a brief history of the activities of the Branch throughout the twenty-five years since its organization. December 15. Attendance 55.

Pennsylvania State College

Industrial Considerations, by F. C. Cramer, student;

Electrical Developments, by V. C. Kauffman, and

Mechanical Developments, by Prof. C. L. Allen, Dept. of Mech. Engg. Prof. Allen also gave a report on the recent Power Show held in New York City. December 14. Attendance 48.

University of Pennsylvania

Business Meeting. October 7. Attendance 53.

Construction and Care of Electrical Instruments, by L. C. Corley, Weston Electrical Instrument Corp. Illustrated with slides. December 8. Attendance 19.

University of Pittsburgh

Proposed Government Control and Investigation of Public Utilities, by M. R. Scharff, Chief Engr., Byllesby Engineering and Management Corp. December 1. Attendance 33.

Copper Oxide Rectifiers, by P. R. Fisher, student, and

Ventilation of Holland Tunnels, by P. E. Lagatolla, student. December 9. Attendance 45.

Architecture of India, by M. R. Malhotra, student. Slides. December 16. Attendance 32.

Princeton University

Television, by W. Wilson, Secretary, and

Mercury Boilers and Turbines, by W. Eakins, student. The following new developments were described by Prof. C. H. Willis: new type commutator; mercury arc rectifier; and the vitaphone. December 8. Attendance 6.

Rensselaer Polytechnic Institute

Rice-Kellogg Exponential Loud Speakers, by Dr. E. W. Kellogg, Research Laboratories, General Electric Co., and

Selenium Cell Application to Television, by Dr. E. W. Kellogg. December 18. Attendance 255.

Rose Polytechnic Institute

Transformers, by Roy Reece, student. Illustrated. January 11. Attendance 41.

Rutgers University

Motion picture on the manufacture of insulation was shown. December 12. Attendance 22.

University of South Dakota

Electrification of Railroads, by Mr. Hayward. December 7. Attendance 7.

University of Southern California

The Repair-Ship "Medusa," United States Navy, by Prof. Eyre. November 2. Attendance 40.

Power Salesmanship, by Mr. Cockfield, Bureau of Power & Light of the City of Los Angeles. November 9. Attendance 34.

Business Meeting. The chairman appointed a committee to work on attendance and membership. December 14. Attendance 25.

Swarthmore College

The Engineer and Manufacturing Costs, by J. E. Hires, Hires, Castner and Harris, Inc. December 15. Attendance 22.

Texas A. & M. College

Some Simplified Methods for Solving for Transients in A-C. Circuits, by Prof. N. F. Rode. January 6. Attendance 85.

University of Texas

A motion picture of the Bell Telephone Laboratories and the Western Electric Company, showing the history and development of the telephone and telephone equipment, was shown. December 7. Attendance 12.

Virginia Polytechnic Institute

Organization and Functions of Our Local Branch, by Prof. Claudius Lee, Counselor. The following officers were elected: Chairman, M. B. Cogbill; Secretary-Treasurer, A. G. Collins. October 26. Attendance 31.

State College of Washington

The American Radio Relay League, by D. H. Sloan, student. December 1. Attendance 33.

Washington University

Storage Batteries in the Bell Telephone System, by A. Pogorelski, student. December 15. Attendance 35.

University of Washington

The Development of Low Starting Current Induction Motors, by Carl Bernhard, student. Illustrated. Discussion of plans for the Open House. December 9. Attendance 24.

Generators and Substations, by J. C. McDougall, Sales Engineer, Westinghouse Electric & Mfg. Co., Seattle. January 6. Attendance 31.

University of Wisconsin

Acoustics, by R. Norris, Burgess Laboratories. Accompanied by demonstration. December 14. Attendance 81.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES DECEMBER 1-31 1927

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Annual Survey of American Chemistry, v. 2; July 1926 July 1927.

Edited by Clarence J. West. Published for National Research Council by Chemical Catalog Company, N. Y., 1927. 415 pp., 8 by 5 in., cloth. $3.00.

This volume gives a brief but connected account of the work done by American chemists during the year, with references to the original publications. The 49 chapters into which the book is divided are each the work of a specialist in some field. The book will be most useful as a survey of the most recent discoveries and applications of chemistry, and as an indicator of lines appropriate for further research.

Although intended primarily for the chemist, many sections, such as those on aluminum, copper, iron and steel, nickel, water

and sewage, clay products, coal and coke, and glass are equally interesting to engineers and manufacturers.

ESSENTIALS OF TRANSFORMER PRACTISE.

By Emerson G. Reed. 2nd edition. N. Y., D. Van Nostrand Co., 1927. 401 pp., illus., diagrs., 9 by 6 in., cloth. $5.00.

In preparing this book, much of which originally appeared in the *Electric Journal* the author has maintained a practical engineering point of view. Theory is discussed, so far as it bears directly on design and operation, the problems and methods of design are set forth, and questions of operation are treated. The new edition has been corrected and a large amount of new matter added.

INDUSTRIAL ART AND THE MUSEUM.

By Charles R. Richards. N. Y., Macmillan Co., 1927. 102 pp., illus., 9 by 6 in., cloth. $1.50.

In this volume Professor Richards supplements his study of industrial museums by one upon museums of industrial art. The first half of the book gives an account of the beginnings of such museums, with accounts of the development and present status of the principal ones in Germany, France and England. A chapter is then given to the place occupied by industrial art in the museum system of this country. Short descriptions of museums in the other European countries are then given, followed by a chapter upon several important special museums.

PROPAGATION OF ELECTRIC CURRENTS IN TELEPHONE AND TELEGRAPH CONDUCTORS.

By J. A. Fleming. 4th edition. N. Y., D. Van Nostrand Co. 1927. 422 pp., illus., diagrs., tables, 9 by 6 in.. cloth. $8.00.

This treatise originated in courses of post-graduate lectures to practical telegraph and telephone engineers, given at the University of London. It aims to present an account of our knowledge of the phenomena connected with the propagation of electric currents in telephone and telegraph conductors, which will enable the engineer to follow the writings of investigators and to solve practical problems as they arise. This edition has been revised, and a new chapter added which treats of recent advances in this field.

STRUCTURAL ENGINEERING; Stresses, Graphical Statics and Masonry.

By George Fillmore Swain. N. Y., McGraw-Hill Book Co., 1927. 525 pp., diagrs., tables, 9 by 6 in., cloth. $5.00.

In this volume, the third of the work, Dr. Swain treats of the theory of statically determined framed structures, and the theory and design of masonary structures.

Both analytical and graphical methods for treating framed structures are given, together with a comprehensive presentation of the subject of graphical statics. In the treatment of masonry structures the fundamental principles are given and the methods of applying them shown, together with the theory of earth pressure.

DER BETONSTRASSENBAU.

By W. Petry. Ber. u. Lpz., Walter de Gruyter & Co., 1927. 112 pp., illus., 6 by 4 in., cloth. 1,50 r. m.

Up to 1914 Germany had built about 300,000 sq. mi. of concrete roads. Their construction then ceased for ten years, but now has been resumed upon a large scale, 260,000 sq. m. having been built in 1926 alone. The present book first reviews briefly the history of concrete road building in Germany prior to 1920. A concise survey of construction in North America is then given, after which the general principles for the construction and maintenance of modern concrete roads are given and illustrated by a series of German examples. A tabulation of data on German road-building in 1925 and 1926 is included.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
53 West Jackson Blvd., Room 1736, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 West 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL ENGINEER OR PHYSICIST, firm in mathematics and a-c. theory. Must be practical and able to apply his knowledge in design department. Work along acoustical lines. Young man preferred. Salary $250 to $500 a month. Apply by letter. Location, near New York. X-4035-C.

MEN AVAILABLE

ELECTRICAL ENGINEER, 30, married, E. E. 1925. Eight years' experience. Four years in supervisory capacity in transmission and distribution engineering; one year in production and five years in technical capacity; graduate of recognized technical college. Experience development, planning, estimating, reports and investigations, substation design, technical and industrial research. Location preferred, Ohio or New York. B-7315.

ELECTRICAL MECHANICAL ENGINEER, 35, single. Honors degree electrical engineering, 15 years' experience design, estimating and application of switching equipment including truck types. Capable, industrious, pleasing personality, wide general knowledge of engineering, able to direct others and accept superior responsibility. Would consider opening in firm manufacturing allied products where opportunity exists for advancement. Location, anywhere. C-3723-1328.

ASSISTANT TO EXECUTIVE, 28, married. Graduate of M. I. T., electrical engineer; two years shop and sales office large electrical manufacturer; two years assistant job engineer, firm of consulting engineers; two years purchasing agent same firm; capable of handling responsible work independently. New York City or New England preferred but not restricted. C-3912.

ELECTRICAL ENGINEER, 36, single. 12 years' experience, including central station design, equipment manufacture and test. Expert on control systems. New York preferred. C-3905.

GRADUATE ELECTRICAL ENGINEER, 24, single. One year out of college. Desires work along theoretical lines in communication or distribution, with large company. Considerable theoretical ability. Some experience in manufacture of telephone apparatus. Location preferred, New York City. C-2967.

RECENT GRADUATE, 24, married. Has had experience in substation operation and maintenance. One season as concrete inspector, two seasons as railway instrumentman. In latter as chief of party. Also has had experience in sales and publicity work. Location, immaterial. C-3962-712-C-4.

DIVISION OR LOCAL MANAGER, 48, married. Sales Engineer speciali/ing rural development past four years, very large company,

desires position, division or local manager where rural development is contemplated. Five years' experience, local manager properties; 22 years, total electric utility experience, construction, operation, maintenance, merchandising. Minimum salary $3300. Location preferred, East, Middlewest, Southwest. C-3966.

RADIO ENGINEER, 28, single. Five years' experience in three of New York's leading broadcasting stations as executive. Thoroughly educated. Have operator's license. Will go anywhere. C-1108.

SALES ENGINEER, 33, single, graduate mechanical, radio and business college, speaking several languages, extensively traveled Europe and Orient-Manchuria, India, Egypt, desires traveling or commercial or technical work where his experiences are valuable. Location preferred, Far East or anywhere. C-3917.

DISTRIBUTION ENGINEER, 39, married, prominent Eastern public utility, creditable record twenty-two years' responsible experience, now free to form new connection as engineer-executive, as personal assistant to outstanding executive or similar capacity; energetic, American. Location preferred, Central Atlantic or Midwest States; not outside of U. S. A. C-3963.

DISTRIBUTION AND TRANSMISSION ENGINEER. Seven years' experience with two large public utility companies, desires to make a new connection with a public utility, preferably in mid-western states. Broad experience in both overhead and underground distribution and transmission, including small substation design, estimating, scheduling, budgeting etc. B-9354.

ELECTRICAL ENGINEER, 30, married. Graduate E. E. General Electric Test 1½ years; electrician and foreman on industrial maintenance and construction 2½ years; 3½ years generating and substation construction, with come experience on station operation, distribution, rates and services. Location preferred, United States, Canada. B-7637.

SALES ENGINEER, of highest caliber. Twelve years' experience in selling and servicing of technical apparatus to Central Station and industrial syndicates in Pennsylvania, Ohio, W. Va., and Western New York. Graduate Electrical Engineer with thorough practical training and wide commercial experience, including advertising. C-2764.

CHIEF ELECTRICIAN OR ASSISTANT, 28, single. Engineering education: 10 years' electrical experience, including construction, central station operation and elevator manufacture. Thoroughly informed theoretically and practically. Elementary Spanish and fluent French. South America or other foreign location preferred. C-3985.

SALES ENGINEER, 31, married. Technical graduate B. E. E. with an additional year in commerce college, principal subjects in marketing Group. Experience; one year estimator for electrical contractor and two years sales analyst for automobile company. Location preferred, Middle West. B 9865.

ELECTRICAL ENGINEER, 36, married. Graduate 1½ years G. E. Test; 8 years substation maintenance and construction, familiar with automatic substations; 3½ years superintendent substation and H. T. underground construction and maintenance. Location preferred, West or Middle West. C-3986.

ELECTRICAL ENGINEER, 40. Twenty years' experience in public utility and industrial engineering. Desires responsible position with utility or large industrial company having charge of the economical selection, layout and installation of electrical equipment. Middle West preferred. B-9485.

TESTMAN, 25, single. Technical graduate (Sweden), Experience; in a chemical laboratory six months, on underground cable construction two years, on standardization and development of instrument and meters, two years and meter testing less than one year. Location mmaterial. C-3911.

GRADUATE ELECTRICAL ENGINEER, 29, single, seven years' experience; A-1 designer and writer of specifications for electrical and mechanical equipment, installation in office buildings, schools, theaters and hospitals. Competant layout man for heating systems, experienced in supervision of electrical and mechanical installations. Desires permanent position, New York City. C-2268.

JUNIOR SALES ENGINEER, 22, single. Cornell graduate, E. E. '27, clean-cut, aggressive type. Interested in motors or fans and blowers. Willing to enter training course. Has had selling experience. Location, preferably New York territory. C-3990.

POWER PLANT ECONOMY ENGINEER, A. S. M. E. and A. I. E. E., 26, single. Two years of general shop work, such as foundry, machine shop, forging and heat treatment, etc. Two years of general power plant experience, such as assembly and testing of steam and oil engines, turbines, their operation and maintenance, substation operation, etc. Location, California or anywhere. C-3978.

ELECTRICAL ENGINEER, 26, single, Swiss, graduate Eidg. Technische Hochschule, Zuerich. 1½ year student course, special study in steel construction, handling of material. Location, Latin America. C-3987.

RECENT GRADUATE, 23, single. Six months of railway signal work, consisting of remodeling interlocking plants, some pole line construction and installation of automatic crossings. Two years selling technical books in a college book store. Location immaterial. C-3981.

ELECTRICAL ENGINEER, 26, five yeras mill construction and maintenance; two years as master electrician; one year central station maintenance; three years G. E. Test. Qualified: Junior Power Engineer, Acceptance Tester, Automatic Machine Switching Specialist. Location, near Providence, R. I. C-3998.

ASSISTANT ELECTRICAL ENGINEER, 24, single. Graduate of recognized technical college. Three years' experience in engineering department of a large public utility operating in the vicinity of New York City. Experience in general, broad but specializing in system protection and relays. Location, New York City or vicinity. B-8793.

DISTRIBUTION ENGINEER, graduate, 25, married. Two years' experience in estimating, design, construction, maintenance distribution systems. Also valuation and investigation electrical systems. C-4001.

EXECUTIVE ENGINEER, 44, married, Protestant, seeks responsible position where 24 years' experience in the industry would appeal. Many years with Westinghouse and Crocker-Wheeler. Departmental manager for five years, ten years' experience design of a-c. and d-c. machinery; latterly considerable sales experience. Unusually broad outlook on problems of the industry. C-30.

ELECTRICAL AND MECHANICAL ENGINEER, graduate, 31, married. 9 years' experience including shop, experimental development, field service, electrical and mechanical design, application, reports, sales-engineering, coordination ideas, efforts of others. Particularly automatic substations, heavy traction. Engineering executive or engineering assistant to executive requiring analytical thought, good judgment. Conscientious, hard worker capable assuming responsibility. C-3913.

POWER PLANT ENGINEER, earning around $12,000 annually past few years, will invest $10,000 to $25,000 with services if conservative opportunity justifies. B-4363.

ASSISTANT EXECUTIVE, 30, married. Degrees E. E. and B. S. Business training. Eight years' diversified electrical and mechanical experience. Supervision four years. New equipment design and development. Transmission and distribution. Some sales experience. Desires connection with manufacturing, consulting or commercial organization requiring executive ability. New York preferred, other locations considered. B-7315.

GRADUATE ELECTRICAL ENGINEER, married. Wishes to obtain position in educational work in electrical engineering. Practical experience includes electrical testing and measurements, power distribution and distribution system maintenance, patent practise in United States and foreign countries in acoustics, radio and allied branches of electrical engineering, some teaching experience. B-9639.

OPERATING ENGINEER. Operation, maintenance, construction hydroelectric plants, substations, transmission lines, pumping plants, machine, electric and meter shops, thirteen years. Navy electrician, four years; steam, electric engineer, two years. International Correspondence School. Navy Electrical School. University of Wisconsin, extension department, mathematics. Alexander Hamilton, modern business. Prefer western location. Salary according to responsibilities. C-3888.

ELECTRICAL ENGINEER, 24, single, 1927 graduate, B. S. degree in E. E., desires permanent position with public utility or manufacturing company dealing in electrical material. Has had five years' practical experience. Location, Chicago. C-3667-738.

JUNIOR ENGINEER, 23, single. Opportunity for advancement desired by electrical-mechanical graduate. Has had varied experience; surveying, highline, substation, switchboard construction. Earned college expenses working in power plant; installing, maintaining equipment and wiring buildings. Location, anywhere in United States. C-4008-1624.

ELECTRICAL ENGINEER, graduate in E. E., 15 years' experience. G. E. Test, anthracite coal fields, large New York State power company, testing maintenance, inspection, electrical drafting and construction of power-houses. substations and transmission lines. Some steel mill experience. C-4012.

GRADUATE ELECTRICAL ENGINEER, 26, single. Two years' central station engineering experience with Westinghouse, also Westinghouse graduate student course. Desires permanent position with either a public utility or industrial concern. Location, immaterial. C-3901-81-C-1.

EXECUTIVE ENGINEER, married. Technical trained electrical engineer with 15 years' experience steam generating stations, construction, operation, maintenance, distribution; desires position as superintendent, 30,000- to 50,000- kw. station; or similar responsible post. Speaks Spanish; knows native labor. Location, anywhere, but preferably foreign. C-1372.

ELECTRICAL ENGINEER, 34, single, degree E. E. Desires position with engineering concern or public utility requiring executive ability. Ten years' experience covering engineering, design and valuation of power plants, substations, transmission and distribution lines. Location, East. B-389.

GRADUATE ELECTRICAL ENGINEER with seven years' experience as superintendent of hydroelectric, rotary converter, and mill electrical equipment, installations, operation and maintenance. Capable organizer, experienced in handling men. Desires position with large manufacturing concern or public utility as electrical superintendent, engineering manager, or in engineering department with opportunity for advancement along executive lines. C-4013.

ELECTRICAL ENGINEER, 20 years' experience. Graduate, 40. Specialist electrical applications. Experienced construction, installation. Just completing installation 12,000 hp in motors, 12,000 kw. in turbo-generators and modernizing 5000 hp. in old motorized equipment large paper mill. Increased production 33 to 50 per cent. Designed, developed successful drives, equipment for paper mills. Also steel mill experience. B-195.

METER SPECIALIST, graduate E. E., 29, married. Ten years' experience in general meter, relay and test engineering with public

utilities. Five years executive. Also considerable experience in distribution, power and industrial engineering. Location, immaterial. C-4017.

ELECTRICAL ENGINEER, American born, Christian, 42. Broad experience in design, development and practical manufacture of electrical apparatus and instruments. Eighteen years' experience in electrical and mechanical engineering and manufacturing work. Thoroughly familiar modern factory organization and administration. Executive, control of manufacturing labor and technical men. B-2721.

TECHNICAL GRADUATE, Bliss Electrical School 1922, 25. Experienced in meter testing both single and polyphase. Also experience in, steel mill electrical construction and maintenance. Location, immaterial. B-7464.

DRAFTSMAN, 26, married. Graduate engineer, three years' drafting experience on municipal, hydroelectric and copper smelter projects and three years' plant experience as supervisor, desires position as draftsman with progressive concern, with chance for advancement. Location, Middle West. C-4015.

CONSTRUCTION FOREMAN, 34, married. Fifteen years' central station experience, including underground high tension cable installations. Technical high school graduate, two years night engineering. A man who really understands his work and can supervise high class installations. B-8839.

GRADUATE ELECTRICAL ENGINEER, 28, single, 4¾ years' varied experience with two large public utility companies. Familiar with overhead distribution as to layout, maintenance, operation and construction. Some experience with gas distribution. Familiar with rates. Have done some research and statistical work. Prefer position as executive's assistant. Location preferred, United States. Good references. C-4027.

ELECTRICAL ENGINEER, 24, married, graduate, transformer design, construction experience; one year purchasing department large public utility; now in charge electrical design of automatic welding machines, desires position where initiative, application analytical ability will insure possibilities for development and advancement. Location, east or middlewest. C-4018.

ELECTRICAL ENGINEER, A. I. E. E. and A. S. M. E., 39, single. 18 years' experience, office and field, design and construction, steam and hydroelectric generating stations, substations, transmission lines distribution systems, industrial power applications and maintenance in plants and buildings. Also testing experience. C-3587.

SALES ENGINEER, 30, married. Five years' sales experience, backed by five year factory and field service with Westinghouse. Technical graduate. Desires sales position where engineering experience will be helpful. Location, vicinity of New York City. C-3990.

ELECTRICAL ENGINEER, 30, graduate, single, wishes employment with a public utility or engineering company in Canada. Broad and thorough experience in the design, construction, and operation of substations, and transmission and distribution systems. Excellent organizing and administrative experience and ability. At present employed as division engineer with large American utility. C-661.

VALUATION ENGINEER, 29, with executive ability to assume responsibility. Electrical Engineering graduate; 3 years in charge of appraisal work on numerous large industrial concerns; experience in equipment installation, building construction cost analysis, engineering reports and estimating. Location preferred, Pacific Coast States. C-4030.

GRADUATE ELECTRICAL ENGINEER desires position with an industrial firm or public utility. Two year Westinghouse test course. Two years' distribution experience. Three years as assistant to electrical engineer of an industrial company. Five years' experience on design and construction of substation and power plants. B-8379.

MAINTENANCE ENGINEER, technical graduate in electrical engineering. Experience covers installation and repairing of apparatus and operating in sub-stations and power stations. More recent experience in textile mills, as assistant to mechanical superintendent covering layouts for new work and changes, including blower systems, lighting, power, heating and ventilating and general mill maintenance. B-3794.

SALES ENGINEER, 37, married. Technical graduate, twelve years' experience in the development, production and sale of railway equipment, including power saving, lubrication, and draft appliances. Has had extensive experience in preliminary surveys, tests and installations. Location, immaterial. B-6873.

ENGINEER, A. S. M. E. and A. I. E. E., 32, married, engineering graduate. Planning, scheduling, estimating, budgetary, rate study. Some operating and design experience; seven years utility and four years industrial; available as assistant or department head. Now with large utility. B-9676.

ELECTRICAL CONSTRUCTION OR OPERATING ENGINEER, 39, married. Wide experience in electrical construction and operation. Sixteen years as division engineer, general superintendent of railways, power plants and substations. Four and one-half years foreign construction service. Adaptable and diplomatic. Spanish spoken. Location preferred, States or Latin America. C-886.

ENGINEER, technical graduate, 34, single, ten years' experience; testing, writing specifications, designing, development and executive work. Would like development work in vicinity of New York City, where new ideas would be of value. B-6970.

ASSISTANT TO OPERATING SUPERINTENDENT, electric utility or traction company, 28, married, electrical graduate Worcester Polytechnic Institute, 15 months Westinghouse course railway and power work in shops, office and field; 2½ years on new electrification, Cleveland, Ohio. 15 months appraisal engineer on distribution, transmission and railway, Tennessee. Permanent position with future. Available immediately. C-3997.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED JANUARY 23, 1928

ANDERSON, ELMER F., Testman, General Electric Co., Schenectady; for mail, Scotia, N. Y.

ARNOLD, ERNEST EVERETT, Substation Operator, Bureau of Power & Light, 1125 Bureau of Power & Light Annex Bldg., Los Angeles, Calif.

ATKINSON, JAMES WILLIAM, Deputy Electrical Engineer, Head Office, British Engine-Boiler & Electrical Insurance Co., Ltd., Fennel St., Manchester, Eng.

BAKER, HAROLD HENRY, Testing Engineer, Electrical Machinery Dept., Royal Indemnity Co., 150 William St., New York, N. Y.

BALDWIN, GURTH, Electrical Contractor, 1105 State St., Erie, Pa.

*BALET, JOHN, Student Engineer, E. L. Phillips & Co., Ocean Ave., Rockville Centre; for mail, Pelham, N. Y.

BATE, HARRY REGINALD C., Electrical Engineer, Mazapil Copper Co., Ltd., Aranzazu, C. del Oro, Zacatecas, Mex.

BATTEN, WENDELL BLAKE, Laboratory Foreman, Westinghouse Elec. & Mfg. Co., East Pittsburgh; for mail, Wilkinsburg, Pa.

*BAUER, PAUL S., Student, Harvard University, Cruft Laboratory, Cambridge, Mass.

BEALES, JOHN T., Jr., Specialty Construction Work, Beales Radio Elec. Co., San Anselmo; for mail, Berkeley, Calif.

*BELL, DELAMAR TURNER, Teaching Fellow, Electrical Engineering Dept., University of Cincinnati, Cincinnati, Ohio.

BENSON, ARTHUR W., Testing Dept., Westinghouse Elec. & Mfg. Co., Springfield, Mass.

BERNARD, WALTER, Engg. Dept., Habirshaw Cable & Wire Corp., Yonkers, N. Y.

BILLINGS, PAGE A., Electrical Engineer, General Electric Co., 920 Western Ave., West Lynn; for mail, East Lynn, Mass.

BINNIE, WILLIAM COLE, Chief Electrician, Consolidated Mining & Smelting Co., Sullivan Concentrator, Chapman Camp, B. C., Can.

BOGGS, JOHN I., Valuation Engg. Dept., Mountain States Tel. & Tel. Co., 800 14th St., Denver, Colo.

BOLLOW, ALBERT JOHN, Jr., Student Engineer, General Electric Co., 1 River Road, Schenectady, N. Y.

*BONANNO, JOSEPH LOUIS, Engineer, Radio Corp. of America, 70 Van Cortlandt Park, South, New York; for mail, Forest Hills, N. Y.

BROWN, GEORGE HENDERSON, Tester, New York Edison Co., 92 Vandam St., New York, N. Y.

*BRUNNER, CARL A., Student, Elec. Test Course, Consolidated Gas & Electric Co., Madison St. Bldg., Baltimore, Md.

*BRYANT, WALTER L., Jr., Student Engineer, General Electric Co., 1 River Road, Schenectady, N. Y.

BUEHNER, ROBERT OTJEN, Electrical Engineer, American Steel & Wire Co., Waukegan, Ill.

*BURRALL, HERBERT STERLING, Theatrical Electrician, Brooklyn Little Theatre, 122 St. Felix St., Brooklyn, N. Y.

*CARLSON, C. PAUL, Telephone Equipment Development, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; for mail, Englewood, N. J.

CARNEGIE, ANDREW, Supt. of Power, Pennsylvania-Ohio Power & Light Co., Youngstown, Ohio.

CARRION, RICARDO ENRIQUE, Traveling Electrician, National Railways of Mexico, Estacion de Colonia-Depto., Elect. y Teleg., Mexico City, Mex.

CHAMPLAIN, CHARLES H., Works Manager, Westinghouse Elec. & Mfg. Co., Sharon, Pa.

CHILES, JOHN HUNTER, Jr., Engineer, Distribution Transformer Engg. Dept., Westinghouse Elec. & Mfg. Co., Sharon, Pa.

CLAPP, NEWMAN BRYANT, Jr., Asst. Foreman, Westinghouse Elec. & Mfg. Co., East Springfield Works, East Springfield; res., Holyoke, Mass.

CLARK, ALBERT M., General Electric Co., 39 E. Genesee St., Buffalo, N. Y.

COHN, BYRON EMANUEL, Instructor, Dept. of Physics, University of Denver, University Park, Denver, Colo.

CONLON, RAYMOND F., Draftsman, Roch-

ester Gas & Electric Corp., 86 Andrews St., Rochester, N. Y.
CONNOR, JOHN FRANCIS, Motor Testing, Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
CONRAD, RALPH WILLIAM, Tester, Westinghouse Elec. & Mfg. Co., East Springfield; for mail, Springfield, Mass.
COOK, WALLACE L., President, Reliable Electric Co., 3145 Carroll Ave.; Chicago, Ill.
COOLEY, CHARLES R., Chief Electrician, Vulcanite Portland Cement Co., Easton, Pa.
DENARDO, JAMES D., Tester, Installation Dept., Western Electric Co., Inc., 1060 Broad St., Newark, N. J.
DERESIENSKI, ALBERT S., Tester, Westinghouse Elec. & Mfg. Co., East Springfield; for mail, Willimansett, Mass.
DOMENZAIN, SALVADOR F., Electrical Engineer, Distribution Dept., Mexican Light & Power Co., Ganta No. 20, Mexico, D. F., Mex.
DONKIN, BYRAN, Student Engineer, General Electric Co.; for mail, International General Electric Co., Schenectady, N. Y.
DUFAULT, JOHN ALEXANDER, Appraisal Engineer, Tennessee Utilities Commission, 727 Power Bldg., Chattanooga, Tenn.
DURGIN, RALPH, Asst. Engineer, General Electric Co., 42 Centre St., West Lynn; for mail, Lynn, Mass.
EAMES, HAROLD F., Small Motor Tester, Westinghouse Elec. & Mfg. Co., Page Blvd., Springfield, Mass.
EATON, TEMPLE OSMAN, Testing Dept., General Electric Co., 1 River Road, Schenectady, N. Y.
EIDEM, EARL LORCK, Designer, Public Service Co. of Northern Illinois, 72 W. Adams St., Chicago, Ill.
*ELLIOTT, DOUGLAS A., Student, Columbia University, New York, N. Y.; for mail, Orange, N. J.
*EVJEN, HAAKON MUUS, Research Assistant, California Institute of Technology, Pasadena, Calif.
*FAIRBURN, ABRAHAM J. B., Instructor in Electrical Engineering, Cooper Union, Hewitt Bldg., New York, N. Y.
FINNEN, W. J., Mechanical Engineer, Engg. Dept., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
*FISHMAN, SOLOMON, Instructor in Electricity, Newark College of Engineering, 367 High St., Newark, N. J.
FORTIER, RALPH LAWRENCE, Test Equipment Designer, Westinghouse Elec. & Mfg. Co., East Springfield; for mail, Springfield, Mass.
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*HAENDLER, ANTON THEODORE, Test Man, Edison Electric Illuminating Co. of Boston, 1165 Massachusetts Ave., Roxbury; for mail, West Roxbury, Mass.
HAGEN, ALBERT M., Asst. Electrical Engineer, Standard Underground Cable Co., Perth Amboy, N. J.
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HALSTEAD, G. W., Jr., Student Engineer, General Electric Co., Schenectady, N Y.
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*KLEIST, MYRON RAYMOND, Student, Armour Institute of Technology, Chicago, Ill.
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*LEERBURGER, FRANKLIN J., Apprentice Engineer, Duquesne Light Co., 435 6th Ave., Pittsburgh, Pa.
LICHT, HENRY M., Service Manager, Williams Hardware Co., Streator, Ill.
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*LISSMAN, MARCEL ALFRED, Electrical Engineer, Western Precipitation Co., 1016 W. 9th St., Los Angeles, Calif.
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LONGOBARDI, BATHOLOMEW GEORGE, Tester, New York Edison Co., 243 A. Reid Ave., Brooklyn, N. Y.
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*METCALF, CHARLES NELSON, General Tester, Testing Dept., New York Edison Co., 92 Vandam St., New York; for mail, Hartsdale, N. Y.
MEUREN, WALTER HENRY, Rola Co., 498 Moss Ave., Oakland, Calif.
MONKHOUSE, WALTER ISAAC, Ass't. Electrical Engineer, Dept. of Public Works, Brisbane, Queensland, Australia.
*MOORE, SAMUEL EARLE, Engineer, Rural Service Dept., Chester Valley Electric Co., 258 E. Main St., Coatesville, Pa.
*MURPHY, MARION E., Junior Engineer, Bell Telephone Laboratories, Inc., Chicago, Ill.
NEWHOUSE, HOMER EARL, Electrical Engineer, Westinghouse Elec. & Mfg. Co., Page Blvd., East Springfield; res., Springfield, Mass.
*NEWTON, EDWARD TAYLOR, Technical Dept., American Brass Co., 414 Meadow St., Waterbury, Conn.
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NOYES, JAMES A., Asst. Operator, Turner Falls Power Co., Turner Falls; res., Springfield, Mass.
*NULL, FAY EDISON, Electrical Engineer, Western Union Telegraph Co., 195 Broadway, New York, N. Y.; for mail, Leonia, N. J.
*O'DWYER, JOHN M., Student Engineer, Southern Sierras Power Co., Riverside, Calif.
OWEN, ROBERT HANCOCK, Engineer in charge KOA, General Electric Co., 1370 Krameria St., Denver, Colo.
*PARSONS, RICHARD B., Elec. Engg. Dept., Narragansett Electric Lighting Co., Providence, R. I.
PETTYJOHN, JOHN GOODE, Testing Dept., General Electric Co., 1 River Road, Schenectady, N. Y.
POWELL, ROBERT WENDELL, Testing Dept., General Electric Co., 1 River Road, Schenectady, N. Y.
REI, PAUL FRANCIS, 3675 Broadway, New York, N. Y.
RONEY, CLYDE ELLIS, Sales Engineer, Westinghouse Elec. & Mfg. Co., 2303 Kennedy St., N. E., Minneapolis, Minn.
RUSH, PHILIP ELIAS, Instructor in Electrical Engineering, University of Pittsburgh, 207 Thaw Hall, Pittsburgh; for mail, Wilkinsburg, Pa.
RUSSOMANDO, ALFONSO M., General Electric Co., 308 Summer Ave., Newark, N. J.
*SABBAGH, ELIAS MORSHED, Graduate Assistant, Michigan State College, East Lansing, Mich.
SAHGAL, SUKHBASHI RAM, Assistant Electrical Engineer, Public Works Dept., Secretariat, Fort, Bombay, India.
SALVATORI, HENRY, Chief of Geophysical Exploration Party (Seismograph), Geophysical Research Corp., 65 Broadway, New York, N. Y.; for mail, Tulsa, Okla.
SCHAEFER, EDWARD J., Electrical Engineer, General Electric Co., Fort Wayne, Ind.
SEDGWICK, ATWOOD, FOSTER, Engineer, Central Hudson Gas & Electric Corp., 611 Broadway, Kingston, N. Y.

SMALL, WILLIAM HENRY H., Electrical Tester, Westinghouse Electric & Mfg. Co., East Springfield; for mail, Springfield, Mass.
SMALLEY, MATTHEW F., Meter Engineer, Ohio Power Co., 606 2nd St., S. E., Canton, Ohio.
SMITH, HARRY BROMILOW, Testing Dept., General Electric Co., Erie; for mail, Lawrence Park, Erie, Pa.
SMITH, LAWRENCE W., Chief Draftsman, English Electric Co. of Canada, St. Catharines, Ont., Can.
*SMITH, REYNOLDS EUGENE, Asst. Engineer, Public Service Co. of Northern Illinois, 1335 Edison Bldg., 72 W. Adams St., Chicago, Ill.
*SOLODOFF, VASILY JACOB, Estimator, Engg. Dept., Westchester Lighting Co., First St. & First Ave., Mt. Vernon, N. Y.
SPANBAUER, RAYMOND J., General Electric Co., 39 E. Genesee St., Buffalo, N. Y.
SPENCER, DONALD NIELANDS, General Manager, Guatemala Gold Dredging Co., Morales, Guatemala, C. A.
STEVENS, CHARLES VERNON, District Sales Manager, Locke Insulator Corp., 1317 Oliver Bldg., Pittsburgh, Pa.
TAYLOR, JOHN BYRD, Asst. Power Engineer, Appalachian Electric Power Co., Lynchburg, Va.
*TIPTON, EARL WALTER, Electrical Engineer, Transformer Engg. Dept., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
*TOWNER, ORRIN WILSON, Radio Apparatus Development Dept., 311-B, Bell Telephone Laboratories, 463 West St., New York, N. Y.
TUCK, HARRY PLAYFORD, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
VON AHN, ADOLPH J., Superintendent, Enterprise Electric Works, 654 Mission St., San Francisco, Calif.
WALLIS, CHARLES WILLARD, Student Engineer, General Electric Co., Lynn, Mass.
WALLIS, CLIFFORD M., Student Engineer, General Electric Co., River Works, Bldg. 86, Lynn, Mass.
WARTH, STANLEY, Div. Transmission Engineer, Southern Bell Tel. & Tel. Co., Jackson, Miss.
*WEEDFALL, WILLIAM WALLACE, Carrier Systems Engineer, Southwestern Bell Telephone Co., 801 Wholesale Merchants Bldg., Dallas, Texas.
*WENTZ, EDWARD CHARLES, Electrical Engineer, Transformer Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; for mail, Wilkinsburg, Pa.
*WILLIAMS, WILLIAM ROWE, Distribution Engineer, Northern States Power Co., Minot, No. Dakota.
*WILSEY, KENNETH CHARLES, Test Engineer, New York Edison Co., 92 Vandam St., New York; for mail, Brooklyn, N. Y.
*WINTER, FRANCIS EDWARD, Student Engineer, General Electric Co., Schenectady, N. Y.
WISE, RAYMOND OWEN, Research Assistant, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*WOLL, WILLARD M., Cadet Electrical Engineer, Northern Indiana Public Service Co., Hammond, Ind.; for mail, Chicago, Ill.
*WOOD, JAMES, Jr., 206 E. 36th St., New York, N. Y.
YOUNG, GLENN S., Industrial Engineer, Kansas City Power & Light Co., 1330 Grand Ave., Kansas City, Mo.

Total 143.

*Formerly enrolled Students.

ASSOCIATES REELECTED JANUARY 23, 1928

BEALE, STANLEY H., Electrical Engineer, Aluminum Co. of American, Massena, N. Y.
MURPHY, HOWARD E., Electrical Engineer, Stone & Webster, Inc., 49 Federal St., Boston, Mass.

MEMBERS ELECTED JANUARY 23, 1928

BALL, THOMAS FAUNTLEROY, Vice-President, Rowe, Ball & Sumwalt, Inc.; Head, Electrical Engineering Dept., University of South Carolina, Columbia, S. C.
CARPENTER, LOUIS G., Consulting Engineer, 702 1st National Bank Bldg., Denver, Colo.
CATE, CARROLL LEE, Consulting Engineer. 1111 Beaver Hall Hill, Montreal, P. Q., Can.
HIND, BERT S., Electrical Superintendent, Andes Copper Mining Co., Casilla B, Potrerillos, via Antofagasta, Chile, So. Amer.
LAWRENCE, JOHN HENRY, Vice-President, Thomas E. Murray, Inc., 55 Duane St., New York, N. Y.
RICHARDSON, HARVEY J., Tata Hydro-Electric Power Supply Co., Ltd., Bombay, India.
SCHAELCHLIN, WALTER, Electrical Engineer, Control Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
TREVINO, GUSTAVO L., In charge, Long Lines Dept., Mexican Tel. & Tel. Co., Donato Guerra 13, Mexico, D. F., Mex.

TRANSFERRED TO GRADE OF FELLOW JANUARY 23, 1928

SEARING, EMERY DeFOREST, Advisory Engineer, Portland Electric Power Co., Portland, Oregon.
SIMONS, DONALD M., Development Engineer, Standard Underground Cable Co., Pittsburgh, Pa.

TRANSFERRED TO GRADE OF MEMBER JANUARY 23, 1928

AMY, ERNEST V., Engineer, Radio Corporation of America, New York, N. Y.
COLEMAN, HARRY C., Manager of Marine Engineering, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
CREIM, B. W., Electrical Engineer, Modesto Irrigation District, Modesto, Calif.
FRAMPTON, ARTHUR H., Assistant Electrical Engineer, Hydro Electric Power Comm., Toronto, Ont. Canada.
HANNON, J. WALTER, General Supt. of Plant, Indiana Bell Telephone Co., Indianapolis, Ind.
HUND, AUGUST, Electrical Engineer, U. S. Bureau of Standards, Washington, D. C.
KINNARD, ISAAC F., Electrical Engineer, General Electric Co., West Lynn, Mass.
KLINE, C. HOWARD, Assistant Engineer, General Electric Co., Pittsfield, Mass.
LARSEN, C. J., Consulting Engineer, Automatic Elec., Inc., Chicago, Ill.
MARSHALL, NORMAN, Mfg. and Consulting Engineer, Bridgeport, Conn.
McANGE, WILLIAM N., President, Inter-Mountain Telephone Co., Bristol, Tenn.
McCULLOUGH, PHILLIP M., Vice President and Chiief Engineer, Mexican Telephone & Telegraph Co., Mexico, D. F. Mexico.
NOBLE, PAUL O., Engineer in charge D. C. Apparatus Dept., General Electric Co., Fort Wayne, Indiana.
ORCUTT, GUY H., Electrical Engineer, Michigan Alkali Co., Wyandotte, Mich.
TILLOTSON, C. C., Electrical Engineer, United Verde Copper Co., Clarkdale, Arizona.
VANDERVOORT, GERALD A., General Supt., N. B. E. P. Comm., St. John, N. B. Canada.
WATERS, JAMES S., Instructor in Electrical Engineering, Rice Institute, Houston, Texas.
WEST, HARRY R., Electrical Engineer, General Electric Co., Pittsfield, Mass.
WINTERER, HORACE K., Commercial Engineer, General Electric Co., Los Angeles, Cal.
WRIGHT, PAUL L., Member of Technical Staff, Bell Telephone Labs., New York.

RECOMMENDED FOR TRANSFER

At its meeting held January 18, 1928, the Board of Examiners recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

TO GRADE OF FELLOW

PIERCE, DANA, President, Underwriters' Laboratories, Chicago, Ill.

TO GRADE OF MEMBER

ANDERSEN, JOHAN M., President, Albert and J. M. Andersen Mfg. Co., Boston, Mass.
BLIEM, HOWARD M., Associate Electrical Engineer, U. S. Bureau of Reclamation, Denver, Colorado.
BOYCE, BENJAMIN K., Chief Engineer, N. Y. Telephone Co., Albany, N. Y.
COTTER, WILLIAM F., Radio Engineer, American Bosch Magneto Corp., Springfield, Mass.
DICKINSON, LEONARD P., Prof. of Electrical Engineering, University of Vermont, Burlington, Vt.
DRAPER, GEORGE W. E., District Switchboard Specialist, General Electric Co., New York, N. Y.
EDGAR, HARRY T., Division Manager, Stone & Webster, Inc., Boston, Mass.
FIELD, HORACE H., Secretary in charge of Research and Investigation for various Working Committees of N. E. L. A. and its Divisions, Chicago, Ill.
GASTONGUAY, EMILE, Manager, Alaska Gold Mines Co., Thane, Alaska.
GEORGE, LEROY E., Distribution Engineer, Philadelphia Electric Co., Philadelphia, Pa.
HUNTER, THOMAS M., Engineer and Sales Manager, American Transformer Co., Newark, N. J.
KEISER, MORRIS, Electrical Engineer, L. H. Wentz Oil Division, Ponca City, Okla.
LAGERSTROM, DAVID R., Asst. to Supt. of Pr., Ht. & Lt., General Electric Co., Schenectady, N. Y.
LIPPINCOTT, DONALD K., Electrical Engineer, Charles S. Evans, Patent Attorney, San Francisco, Cal.
MAHOOD, EDWIN T., Engineer, Southwestern Bell Telephone Co., Kansas City, Mo.
MIDGLEY, HARRY, Switchboard Engineer, British Thomson Houston Co., Ltd., London, N. W., England.
MURDOCK, ALFRED W., Assistant Engineer, Hydro-Electric Pr. Com., Toronto, Ont., Canada.
O'BANION, ALBERT LEE, Instructor in Electrical Engineering, Cornell University, Ithaca, N. Y.
ROE, FREMONT L., Phoenix, Arizona.
RUBEL, WALTER G., Transmission Engineer, Mountain States Tel. & Tel. Co., Denver, Colorado.
VANDERSLUIS, WARREN M., Electrical Engineer, Chicago Terminal Improvement, Illinois Central Railroad, Chicago, Ill.
YUILL, ALEXANDER C. R., Consulting Engineer, Vancouver, B. C., Canada.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before February 29, 1928.

Abakumoff, K. V., Texas Power & Light Co., Dallas, Texas
Abbott, L., Stone & Webster, Inc., Boston, Mass.
Ahlstroem, K. E., Stone & Webster, Inc., Boston, Mass.

Arnell, J. C., Brooklyn Edison Co., Brooklyn, N. Y.
Arvidson, C. E., Commonwealth Power Corp., Jackson, Mich.
Babcock, F. H., General Electric Co., New York, N. Y.
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Beedy, H., Western Electric Co., Chicago, Ill.
Blake, Ivan A., Stone & Webster, Inc., Boston, Mass.
Blomquist, E. A., Rensselaer Polytechnic Institute, Troy, N. Y.
Bonham, W. E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Bonner, J. R., Electrical Contractor, Alturas, Calif.
Brandt, R. H., General Electric Co., Schenectady, N. Y.
Brevoort, H. W., New York Edison Co., New York, N. Y.
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Brownlee, W. N., Stone & Webster, Inc., Boston, Mass.
Cawdrey, M. M., Columbia Engg. & Mgt. Corp., Cincinnati, Ohio
Chiofale, F. P., Brooklyn Edison Co., Brooklyn, N. Y.
Chitty, H. R., Jr., Home Tel. & Tel. Co., Spokane, Wash.
Clark, K. B., Burlington Public Elevator Co., St. Joseph, Mo.
Cozzens, B., San Jose, Calif.
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Davidson, J. I., Montana Power Co., Butte, Mont.
Davis, G. W., Penn-Ohio Power & Light Co., Andover, Ohio
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Ekey, F. J., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Eppley, I. C., Columbia Engineering & Management Corp., Dayton, Ohio
Errickson, J. E., Camden Coke Co., Plant of Public Service Elec. & Gas Co., Camden, N. J.
Evans, E. A., General Electric Co., Schenectady, N. Y.
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Fenstermacher, G. D., Allentown School District, Allentown, Pa.
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Fischer, Hyman, 723 5th Ave., San Francisco, Calif.
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Setzer, M. W., Canadian School of Electricity, Montreal, P. Q., Can.
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Smith, G. V., Bell Telephone Laboratories, New York, N. Y.
Smith, H. C., Southern California Edison Co., Los Angeles, Calif.
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Swiedom, K. L., West Texas Utilities Co., Abilene, Texas
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von Hoorn, F. G., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
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Worthington, E., Stone & Webster, Inc., Boston, Mass.
Wright, R. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Total 135.

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Dev, S. R., Military Power House, Ferozepore Cantt., Punjab, India
Hayden, A. J., Electrical Contractor, Otahuhu, N. Z.
Macaulay, J. H., Bombay, Baroda & Central India Rwy. Co., Dohad, India
Robinson, T. L., City of Salford Electricity Dept., Salford, Eng.
Serra Negra, F. S., (Member), Rede de Viacao Sul Mineira, Cru Leiro, Sao Paulo, Brazil, S. Amer.
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Total 6.

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McDonald, Thomas B., Rice Institute
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Reichert, Harold E., Marquette University
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Philadelphia	I. M. Stein	R. H. Silbert, 2301 Market St., Philadelphia, Pa.
Pittsburgh	W. C. Goodwin	H. E. Dyche, University of Pittsburgh, Pittsburgh, Pa.
Pittsfield	H. O. Stephens	F. R. Finch, General Electric Co., Pittsfield, Mass.
Portland, Ore.	J. E. Yates	L. M. Moyer, General Electric Co., Portland, Ore.
Providence	F. N. Tompkins	F. W. Smith, Blackstone Valley Gas & Electric Co., Pawtucket, R. I.
Rochester	R. D. De Wolf	C. C. Eckhardt, Igrad Condenser & Mfg. Co., 26 Ave. D, Rochester, N. Y.
St. Louis	L. F. Woolston	L. P. Van Houten, 2670 Washington Boulevard, St. Louis, Mo.
San Francisco	W. L. Winter	A. G. Jones, 807 Rialto Bldg., San Francisco, Calif.
Saskatchewan	J. D. Peters	W. P. Brattle, Dept. of Telephones, Telephone Bldg., Regina, Sask., Canada
Schenectady	T. A Worcester	R. F. Franklin, Room 301, Bldg. No. 41, General Elec. Co., Schenectady, N. Y.
Seattle	C. R. Wallis	Ray Rader, Puget Sound Pr. & Lt. Co., Seattle, Wash.
Sharon	L. H. Hill	H. B. West, Westinghouse Elec. & Mfg. Co , Sharon, Pa.
Southern Virginia	W. S. Rodman	J. H. Berry, 1338 Rockbridge Ave., Norfolk, Va.
Spokane	L. R. Gamble	James B. Fisken, Washington Water Power Co., Lincoln & Trent, Spokane, Wash.
Springfield, Mass.	C. A. M. Weber	B. V. K. French, American Bosch Magneto Corp., Springfield, Mass.
Syracuse	C. E. Dorr	F. E. Verdin, 615 City Bank Bldg., Syracuse, N. Y.
Toledo	T. J. Nolan	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio
Toronto	C. E. Sisson	F. F. Ambuhl, Toronto Hydro-Elec. System, 226 Yonge St., Toronto, Ont., Canada
Urbana	J. O. Kraehenbuehl	J. K. Tuthill, 106 Transportation Bldg., University of Illinois, Urbana, Ill.
Utah	Daniel L. Brundige	C. B. Shipp, General Electric Co., Salt Lake City, Utah
Vancouver	A. C. R. Yuill	J. Teasdale, British Columbia Elec. Railway Co., Vancouver, B. C., Canada
Washington, D. C.	M. G. Lloyd	H. E. Bradley, Potomac Elec. Pr. Co., 14th & C Sts., N. W., Washington, D. C.
Worcester	Guy F. Woodward	F. B. Crosby, Morgan Construction Co., 15 Belmont St., Worcester, Mass.
Total 52		

LIST OF BRANCHES

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
Akron, Municipal University of, Akron, Ohio	C. R. Delagrange	P. W Bierman	J. T. Walther
Alabama Polytechnic Institute, Auburn, Ala	T. S. Lynch	P. E. Sandlin	W. W. Hill
Alabama, University of, University, Ala	Sewell St. John	J. M. Cardwell, Jr.	
Arizona, University of, Tucson, Ariz	Gary Mitchell	Audley Sharpe	J. C. Clark
Arkansas, University of, Fayetteville, Ark	W. H. Mann, Jr.	Dick Ray	W. B. Stelzner
Armour Institute of Technology, 3300 Federal St., Chicago, Ill	L. J. Anderson	H. T. Dahlgren	D. P. Moreton
Brooklyn Polytechnic Institute, 99 Livingston St., Brooklyn, N. Y	James Brown	F. W. Campbell	Robin Beach
Bucknell University, Lewisburg, Pa	G. B. Timm	A. C. Urffer	W. K Rhodes
California Institute of Technology, Pasadena, Calif	J. W. Thatcher	J. G. Kuhn	R. W. Sorensen
California, University of, Berkeley, Calif	John F. Bertucci	Nathan C. Clark	T. C. McFarland
Carnegie Institute of Technology, Pittsburgh, Pa	N. D. Cole	J. R. Britton	B. C. Dennison
Case School of Applied Science, Cleveland, Ohio	G. J. Currie	R. C. Taylor	H. B. Dates
Catholic University of America, Washington, D. C	J. V. O'Connor	R. H. Rose	T. J. MacKavanaugh
Cincinnati, University of, Cincinnati, O	C. E. Young	W. C. Osterbrock	W. C. Osterbrock
Clarkson College of Technology, Potsdam, N. Y	G. L. Rogers	J. S. Loomis	A. R. Powers
Clemson Agricultural College, Clemson College, S. C	A. P. Wylie	W. J. Brogdon	S. R. Rhodes
Colorado, University of, Boulder, Colo	J. A. Setter	H. R. Arnold	W. C. DuVall
Colorado State Agricultural College, Fort Collins, Colo	Harold Groat	Howard Steinmetz	H. G. Jordan
Cooper Union, New York, N. Y	E. T. Reynolds	Wilfred Henschel	N. L. Towle
Denver, University of, Denver, Colo	G. K. Baker	L. L. Booth	R. E. Nyswander
Drexel Institute, Philadelphia, Pa	J. E. Young	C. J. Backman	E. O. Lange
Duke University, Durham, N. C	O. T. Colclough	F. A. Bevacqua	W. J. Seeley
Florida, University of, Gainesville, Fla	W. H. Johnson	A. C. Dean	J. M. Weil
Georgia School of Technology, Atlanta, Ga	J. A. Hart	O. P. Cleaver	E. S. Hannaford
Idaho, University of, Moscow, Idaho	R. G. Elliott	F. B. Peterson	J. H. Johnson
Iowa State College, Ames, Iowa	W. H. Curvin	W. H. Stark	F. A. Fish
Iowa, State University of, Iowa City, Iowa	F. L. Kline	M. B. Hurd	A. H. Ford
Kansas State College, Manhattan, Kansas	R. D. Bradley	E. C. Shenk	R. G. Kloeffler
Kansas, University of, Lawrence, Kans	R. M. Alspaugh	W. A. Wolfe	G. C. Shaad
Kentucky, University of, Lexington, Ky	H. M. Otto	D. M. James	W. E. Freeman
Lafayette College, Easton, Pa	John W. Dagon	H. W. Lovett	Morland King
Lehigh University, Bethlehem, Pa	H. C. Towle, Jr.	W. D. Goodale, Jr.	J. L. Beaver
Lewis Institute, Chicago, Ill	A. R. Sansone	G. M. Berg	F. A. Rogers
Louisiana State University, Baton Rouge, La	R. C. Alley	Henry Joyner	M. B. Voorhies
Maine, University of, Orono, Maine	R. F. Scott	E. W. Jones	Wm. E. Barrows, Jr.
Marquette University, 1200 Sycamore St., Milwaukee, Wis	J. R. Adriansen	H. J. Lavigne	J. F. H. Douglas
Massachusetts Institute of Technology, Cambridge, Mass	W. M. Hall	H. F. Krantz	W. H. Timbie
Michigan State College, East Lansing, Mich	K. E. Hunt	S. W. Luther	L. S. Foltz
Michigan, University of, Ann Arbor, Mich	L. J. VanTuyl	W. E. Reichle	B. F. Bailey
Milwaukee, Engineering School of, 415 Marshall St., Milwaukee, Wis	Joseph Havlick	H. F. Brundage	John D. Ball
Minnesota, University of, Minneapolis, Minn	G. C. Brown	G. C. Hawkins	H. Kuhlmann
Mississippi Agricultural & Mechancal College, A. & M. College, Miss	H. M. Stainton	R. S. Kersh	L. L. Patterson
Missouri School of Mines & Metallurgy, Rolla, Mo	H. H. Brittingham	E. J. Gregory	I. H. Lovett
Missouri, University of, Columbia, Mo	C. E. Schooley	W. D. Johnson	M. P. Weinbach
Montana State College, Bozeman, Mont	W. F. Kobbe	G. E. West	J. A. Thaler
Nebraska, University of, Lincoln, Neb	W. A. Van Wie	Keith Davis	F. W. Norris
Nevada, University of, Reno, Nevada	K. K. Knopf	Clark Amens	S. G. Palmer
Newark College of Engineering, 367 High St., Newark, New Jersey	E. S. Bush	Henry L. Harrison	J. C. Peet
New Hampshire, University of, Durham N. H	S. S. Appleton	H. B. Rose	L. W. Hitchcock

LIST OF BRANCHES—*Continued.*

Name and Location	Chairman	Secretary	Counselor (Member of Faculty)
New York, College of the City of, 139th St. & Convent Ave., New York, N. Y.	Joseph Leipziger	A. H. Rapport	Harry Baum
New York University, University Heights, New York, N. Y.	J. F. Torpie	R. J. Fluskey	J. Loring Arnold
North Carolina State College, Raleigh, N. C.	J. C. Davis	T. C. Farmer	C. W. Ricker
North Carolina, University of, Chapel Hill, N. C.	D M. Holshouser	W. C. Burnett	P. H. Daggett
North Dakota, University of, University Station, Grand Forks, N. D.	Alfred Botten	Nels Anderson	D. R. Jenkins
Northeastern University, 316 Huntington Ave., Boston 17, Mass.	L. A. Smith	C. S. Porter	Wm. L. Smith
Notre Dame, University of, Notre Dame, Ind.	Charles Topping	George Conner	J. A. Caparo
Ohio Northern University, Ada, O.	John Simmons	Verl Jenkins	I. S Campbell
Ohio State University, Columbus, O.	A. B. Crawford	L. G. Stewart	F. C. Caldwell
Ohio University, Athens, O.	Clarence Kelch	H. W. Giesecke	A A. Atkinson
Oklahoma A. & M. College, Stillwater, Okla.	Benny Fonts	Jerry Robertson	Edwin Kurtz
Oklahoma, University of, Norman, Okla.	Dick Mason	S. Hannon	F. G. Tappan
Oregon State College, Corvallis, Ore.	J D. Hertz	Richard Setterstrom	F. O. McMillan
Pennsylvania State College, State College, Pa.	Carl Dannerth	W. J. Gorman	L. A. Doggett
Pennsylvania, University of, Philadelphia, Pa.	Wm. H. Hamilton	S. R. Warren, Jr.	C. D. Fawcett
Pittsburgh, University of, Pittsburgh, Pa.	K. A. Wing	R. H. Perry	H. E. Dyche
Princeton University, Princeton, N. J.	R. W. MacGregor, Jr.	W. Wilson	Malcolm MacLaren
Purdue University, Lafayette, Indiana	H. L. Lindstrom	H. A. Hartley	A. N. Topping
Rensselaer Polytechnic Institute, Troy, N. Y.	W. F. Hess	S. B. Morehouse	F. M. Sebast
Rhode Island State College, Kingston, R. I.	C. F. Easterbrooks	Charles Miller	Wm. Anderson
Rose Polytechnic Institute, Terre Haute, Ind.	Arthur Drompp	J. F. Payne	C. G. Knipmeyer
Rutgers University, New Brunswick, N. J.	N. A. Kieb	J. E. Conover	P. S. Creager
Santa Clara, University of, Santa Clara, Calif.	R. P. O'Brien	C. E. Newton	A. D. Hinckley
South Dakota State School of Mines, Rapid City, S. D.	D. A. White	Robert Mytinger, Jr.	J. O. Kammerman
South Dakota, University of, Vermillion, S. D.	Stanley Boegler	L. E. Crowell	B. B. Brackett
Southern California, University of, Los Angeles, Calif.	Lester Bateman	L. F. Slezak	P. S. Biegler
Stanford University, Stanford University, Calif.	D. E. Chambers	T. L. Lenzen	T. H. Morgan
Stevens Institute of Technology, Hoboken, N. J.	W. N. Goodridge	S. J. Tracy	F. C. Stockwell
Swarthmore College, Swarthmore, Pa.	T. C. Lightfoot	W. F. Denkhaus	Lewis Fussell
Syracuse University, Syracuse, N. Y.	E. D. Lynde	R. C. Miles	C. W. Henderson
Tennessee, University of, Knoxville, Tenn.	J. R. McConkey	R. L. Harvey	C. A. Perkins
Texas, A. & M. College of, College Station, Texas	J. L. Pratt	H. W. Whitney	C. C. Yates
Texas, University of, Austin, Texas	G. E. Schade	L. R. Bagwell	J. A. Correll
Utah, University of, Salt Lake City, Utah	C. E. White	Junior Petterson	J. F. Merrill
Virginia Military Institute, Lexington, Va.	F. Barkus	E. F. James	S. W. Anderson
Virginia Polytechnic Institute, Blacksburg, Va.	M. B. Cogbill	A. G. Collins	Claudius Lee
Virginia, University of, University, Va.	H. D. Forsyth	C. H. Davis, Jr.	W. S. Rodman
Washington, State College of, Pullman, Wash.	Harry Wall	E. G. Peters	R. D. Sloan
Washington University, St. Louis, Mo.	R. L. Belshe	J. G. Mazanec, Jr.	H. G. Hake
Washington, University of, Seattle, Wash.	Wm. Bolster	Arthur Peterson	G. L. Hoard
Washington and Lee University, Lexington, Va.	R. E. Kepler	Bernard Yoepp	R. W. Dickey
West Virginia University, Morgantown, W. Va.	G. B. Pyles	C. C. Coulter	A. H. Forman
Wisconsin, University of, Madison, Wis.	John Sargent	Leonard Saari	C. M. Jansky
Worcester Polytechnic Institute, Worcester, Mass.	A. M. Tarbox	M. A. Swanson	H. A. Maxfield
Wyoming, University of, Laramie, Wyoming	J. O. Yates	E. C. Moudy	G. H. Sechrist
Yale University, New Haven, Conn.	W. J. Brown	W. T. Kelly, Jr.	C. F. Scott
Total 95			

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Outdoor Station Equipment.—Bulletin GEA-748A, 20 pp. Describes G-E bus supports for outdoor service. General Electric Company, Schenectady, N. Y.

Floodlighting.—Bulletin GEA-439A, 10 pp., is titled "A Short Cut to the Solution of Floodlighting Problems," General Electric Company, Schenectady, N. Y.

Circuit Breakers.—Bulletin 580, 20 pp. Describes an extensive line of enclosed circuit breakers, of three distinct types, each type having its own particular application. Roller-Smith Company, 12 Park Place, New York.

High Potential Fuses.—Bulletin 200A, 20 pp. Describes the S & C high potential fuse and its applications. Capacities are 2,200 to 132,000 volts, ½ to 400 amperes. Schweitzer & Conrad, Inc., 4435 Ravenswood Avenue, Chicago, Ill.

Oil Fuse Cutouts.—Bulletin GEA-732A, 10 pp. Describes D & W oil fuse cutouts, type D. These are used primarily for the protection of distribution and small power transformers. General Electric Company, Schenectady, N. Y.

Pole Line Hardware.—Catalog 28, 192 pp. Describes a comprehensive line of pole line hardware and construction specialties used by electric light and power companies, telephone companies and railroad companies. The catalog has been designed as a reference book and contains many useful construction methods of primary and secondary distribution. Hubbard & Company, 62nd St. and A. V. R. R., Pittsburgh, Penn.

Time Recorder.—Bulletin 1127, 8 pp. Describes the new Esterline-Angus time recorder which records the actual time and duration of occurrences. It has wide application in the electrical field; in power plants, for recording the time when switches or valves are opened and closed; in automatic substations, to record the operation of circuit breakers and automatic switches, the stopping and starting of equipment, etc.; and on street lighting circuits, where electric service companies are required to provide instruments which record when each circuit is in operation. Esterline-Angus Company, Indianapolis, Ind.

Ground Tester.—Bulletin 1165, 12 pp. Describes the "Megger" ground resistance tester, a new direct-reading electrical instrument for testing the resistance to earth of ground connections. It is entirely self-contained, requiring no external current supply or any auxiliary apparatus whatever, except two ground rods and flexible leads. The test is made in one operation and with only one reading. The result is indicated directly on the schedule, which reads like a voltmeter. No adjustment or calculations are necessary. James G. Biddle, 1211 Arch Street, Philadelphia, Penn.

NOTES OF THE INDUSTRY

Corning Glass Works, Corning, N. Y., has appointed Thomas S. Wood as representative, with headquarters in the Polson Building, Seattle, Washington, to handle only the sale of Pyrex insulators in the states of Oregon and Washington.

The Wadsworth Electric Manufacturing Company, Covington, Ky., manufacturers of switches and meter protective devices, announces the election of Roy Cosbey as director and secretary to fill the vacancy caused by the death of Richard J. Dibowski. Mr. Cosbey for the past four years has been comptroller of the company.

New Large Portable Blower.—The Martindale Electric Company, 1254 West 4th Street, Cleveland, Ohio, has recently developed the "Martindale" portable super-blower with 27 in. water column pressure. The new blower is claimed to be about twenty-five per cent stronger than their former "Imperial" super-blower.

New Ohio Brass Office in South.—The Ohio Brass Company, Mansfield, Ohio, announces the opening of an office in the Healy Building, Atlanta, Georgia, to render better service to the trade in the southeast, and it will be used as headquarters by K. V. Farmer, H. H. Hoxie, J. A. Whatley and G. W. Willis, sales representatives of the company in that part of the country.

Norma-Hoffmann Bearings Corporation, Stamford, Conn., announces the resignation of A. H. Grayburn, assistant secretary and assistant treasurer. He will assume an important executive position with the Hope Engineering and Supply Company, of Mount Vernon, Ohio and New York City. A. H. Ritter, New York district manager goes to Stamford as assistant secretary and will be succeeded in New York by F. W. Mesinger from the Stamford office. Norman Bell, assistant sales manager, has also been made assistant secretary.

Changes in Roller-Smith Personnel.—The Roller-Smith Company, 12 Park Place, New York, makers of instruments, relays and circuit breakers, has added S. H. King to its sales force in New York City. Albert Milmow, Charlotte, N. C., has been appointed exclusive agent for the states of North and South Carolina. M. B. Mathley, Monadnock Building, Chicago, has been appointed exclusive agent for the Chicago territory, superseding M. Frankel. W. J. Schuhmann, who has been connected with the New York office for many years as sales engineer, has been transferred to the company's works at Bethlehem, Pa.

New Branch Offices for Allis-Chalmers.—The Allis-Chalmers Manufacturing Company, Milwaukee, has opened a new district sales office at Phoenix, Arizona, located in the Heard Building, with J. B. Cooper as manager. Mr. Cooper's headquarters were formerly in Los Angeles. A branch office has been opened at San Antonio, Texas, in the Frost National Bank Building, with Earle R. Hury in charge. Another branch office is also being opened at Grand Rapids, Michigan, in the Weiss Service Building, in charge of G. C. Culver.

Cutler-Hammer Opens Pacific Coast Offices.—The Pacific Coast offices of the Cutler-Hammer Manufacturing Company, Milwaukee, will be handled by their own sales offices, at 970 Folsom Street, San Francisco; 229 Boyd Street, Los Angeles; 2204 First Avenue, South, Seattle. The new sales district will be in charge of Fred H. Oberschmidt, a member of the Cutler-Hammer organization for over fifteen years. Associated with him at the San Francisco headquarters will be A. A. Tuffert and George P. Stone. Thomas N. Bristow will be in charge of the Seattle office, and Edward G. Nelson of the Los Angeles office. Complete stocks of standard items in the Cutler-Hammer line will be carried at all Pacific coast offices.

National Carbon Opens New Branch Sales Offices.—The carbon sales division of the National Carbon Company, Inc., with general sales headquarters in Cleveland, has announced the opening of branch sales offices to be located at the present brush service plants of the company at 357 West 36th Street, New York; 551 West Monroe Street, Chicago, and Arrott Power Bldg. No. 3, Barker Place, Pittsburgh. Complete sales and service organizations have been established at each office, and the customers of the company have been requested to address all orders and inquiries for carbon brushes and other carbon specialties to the nearest branch sales office. The following appointments have also been announced: J. A. Hammond, assistant manager in charge of carbon brush and specialty sales. Mr. Hammond will be located at the headquarters office at Cleveland; E. R. Geib, assistant manager in charge of sales of illuminating carbons, who will be located in Cleveland; J. L. Green, district manager in charge of the branch office at Chicago; V. J. Nolan, district manager in charge of the branch office at Pittsburgh; J. B. Collins, sales engineer in charge of the branch office at Birmingham, Ala.